AN AUTOMATIC MESH GENERATOR USING TWO AND THREE-DIMENSIONAL ISOPARAMETRIC FINITE ELEMENTS

James R. Adamek

NAVAL POSTGRADUATE SCHOOL
Monterey, California

THESIS

AN AUTOMATIC MESH GENERATOR
USING TWO AND THREE-DIMENSIONAL
ISOPARAMETRIC FINITE ELEMENTS

by

James R. Adamek

Thesis Advisor: G. Cantin

June 1973

Approved for public release; distribution unlimited.

An Automatic Mesh Generator Using Two and Three-dimensional Isoparametric Finite Elements

by

James R. Adamek
Lieutenant, United States Navy
B.S., University of Oklahoma, 1965

Submitted in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE IN MECHANICAL ENGINEERING

from the

NAVAL POSTGRADUATE SCHOOL
June 1973

ABSTRACT

The objective of the project described in this report was to develop computer systems which would generate the element connectivity, and nodal point co-ordinates for two and three-dimensional finite element programs using isoparametric finite elements. The computer systems and sample problems are discussed.

TABLE OF CONTENTS

ACKNOWLEDGMENT

The author wishes to express his appreciation to Professor Gilles Cantin who introduced this author to the finite element method of structural analysis and to the concept of automatic mesh generation and who provided his moral support, encouragement and assistance throughout the development of this project.

I. INTRODUCTION

The increased popularity of the Finite Element analytical method due to the availability of high speed, large memory computers has led to the solution of many heretofore unsolvable problems in structural analysis. Although users of this method welcome the greater freedom given them to pursue more fundamental problems, they are presented the tedious task of generating and checking the mesh input data of their particular computer system. This data includes the arrangement of nodes within each finite element (connectivity) and the co-ordinates of all the nodes.

Automatic mesh generation is an attempt at simplifying input data for the finite element programs. If the user can communicate with the computer in a better, faster, and more efficient manner, money and labor will be substantially saved, and the possibility of human error will be greatly reduced.

Many automatic mesh generation schemes exist, however these systems are normally proprietary, very specialized, and not generally adaptable to finite elements having side nodes. The present system is an attempt to remedy that situation.

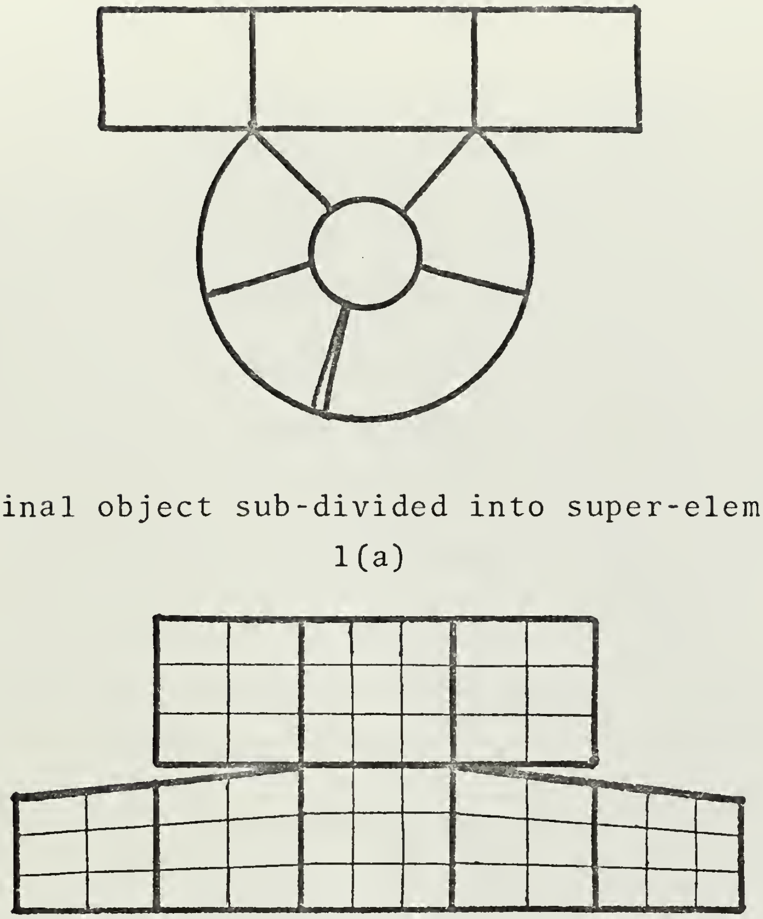
References 3 and 6 prompted this author to devise a code for two and three-dimensional automatic mesh generation schemes, utilizing the technique of mapping from a local

non-dimensional system of reference into the global cartesian system of reference.

Reference 4 is a previous work on a three-dimensional automatic mesh generation scheme using isoparametric elements, however the coding incorporated an interpolation scheme which led to ill-conditioned elements in some instances.

To illustrate the effect of reduction in the amount of data as a result of automatic mesh generation, the following example is introduced: Figure 1(a) is a rather complex geometrical shape in the x-y plane, which can be sub-divided into sections (super-elements) for which one of the isoparametric elements is a very close geometric approximation. These super-elements may be further discretized into smaller elements. The connection of the super-elements and elements is more easily illustrated in a local non-dimensional system of co-ordinates, as shown in Figure 1(b), where all the super-elements are squares. With the appropriate boundary description of the super elements as shown in Figure 1(a), and a super-element connectivity diagram as shown in Figure 1(b), the fine grid of figure 1(b) can be mapped back into the original object to produce the desired mesh of Figure 2.

Four automatic mesh generation schemes will be presented in this thesis. One is for two-dimensional linear, quadratic and cubic elements. The others for three-dimensional linear, quadratic and cubic elements respectively.



Original object sub-divided into super-elements

1(a)

Connectivity of super-elements in local system

1(b)

Figure 1. SEL Diagrams.

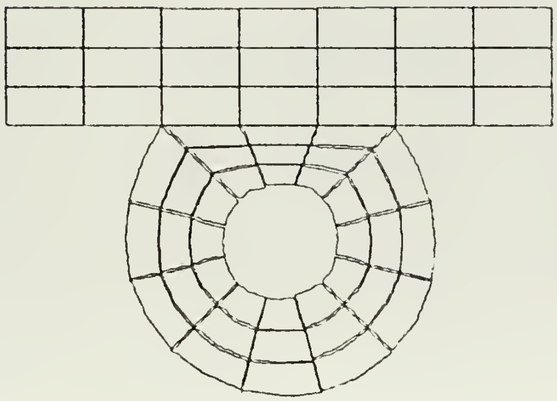


Figure 2. Final Mesh.

II. ISOPARAMETRIC FINITE ELEMENTS

The isoparametric concept will be discussed in this chapter in sufficient detail to establish only the procedures for constructing isoparametric elements and the validity of relationships used to obtain a mapping from the local non-dimensional reference into the global cartesian system of reference. The readers are referred to references 1 and 2 for further details of the isoparametric concept.

The serendipity family of isoparametric elements [1] was utilized in this paper due to the ease of transformation (mapping) from a local non-dimensional system of coordinates, where all elements are squares or cubes, to a cartesian system with curvilinear boundaries.

A. TWO-DIMENSIONAL ELEMENTS

Consider the square isoparametric elements of Figure 3. Figure 3(a) is a linear element consisting of four corner nodes.

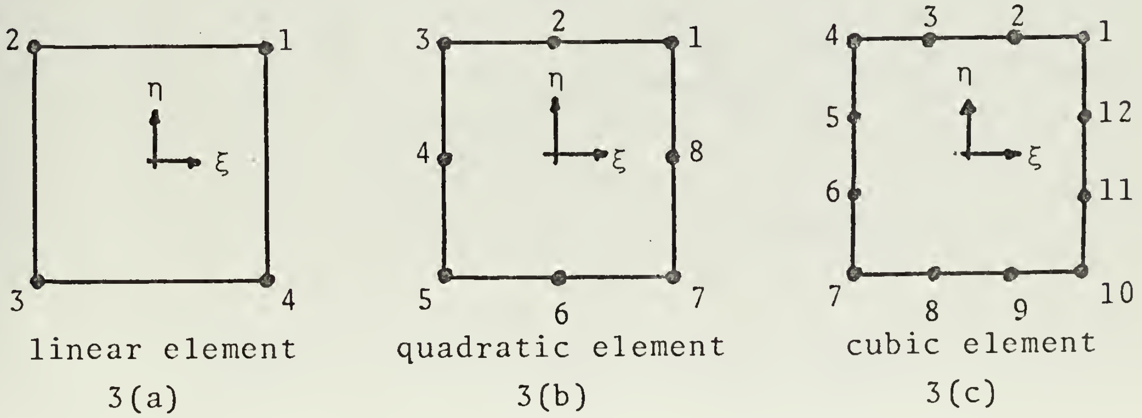


Figure 3. Isoparametric Element Configurations in Local (ξ,η) Coordinates.

Figure 3(b) is a quadratic element consisting of four corner nodes and four side nodes. Figure 3(c) is a cubic element consisting of four corner nodes and eight side nodes.

A curvilinear element, such as that of Figure 4, may be produced by mapping the appropriate square of Figure 3 into the x-y plane using the relations

$$x = \sum_{i=1}^{n} N_i x_i \quad ; \quad y = \sum_{i=1}^{n} N_i y_i \qquad (1)$$

where (x_i, y_i) are the cartesian coordinates of node i. N_i are shape functions of the serendipity family, listed in Section II.C.1., n is the number of nodes on the element (i.e., 4 for linear elements, 8 for quadratic elements, 12 for cubic elements).

Note that the convention for node numbering within any element (see Figures 3 and 4) is to begin at $(\xi, \eta) = (1,1)$ and to number the nodes proceeding counterclockwise.

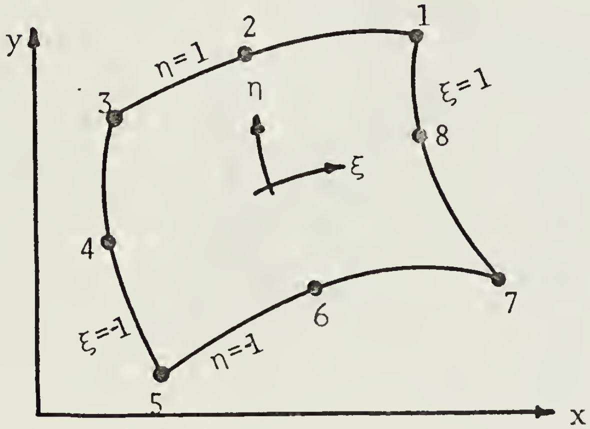


Figure 4. Curvilinear Element Mapped in Cartesian Coordinates.

B. THREE-DIMENSIONAL ELEMENTS

Linear elements, Figure 5, have eight corner nodes. Quadratic elements, Figure 6, have eight corner nodes and twelve side nodes. Cubic elements, Figure 7, have eight corner nodes and twenty-four side nodes.

Similarly, as with two-dimensional elements, three-dimensional curvilinear elements may be produced (mapped) using the relations

$$x = \sum_{i=1}^{n} N_i x_i \quad ; \quad y = \sum_{i=1}^{n} N_i y_i \quad ; \quad z = \sum_{i=1}^{n} N_i z_i$$

where (x_i, y_i, z_i) are the cartesian coordinates of node i. As shown in Figures 5, 6 and 7, the convention for node numbering within any element is to begin at $(\xi, \eta, \zeta) = (1,1,1)$ and to number the nodes proceeding counterclockwise about the zeta axis.

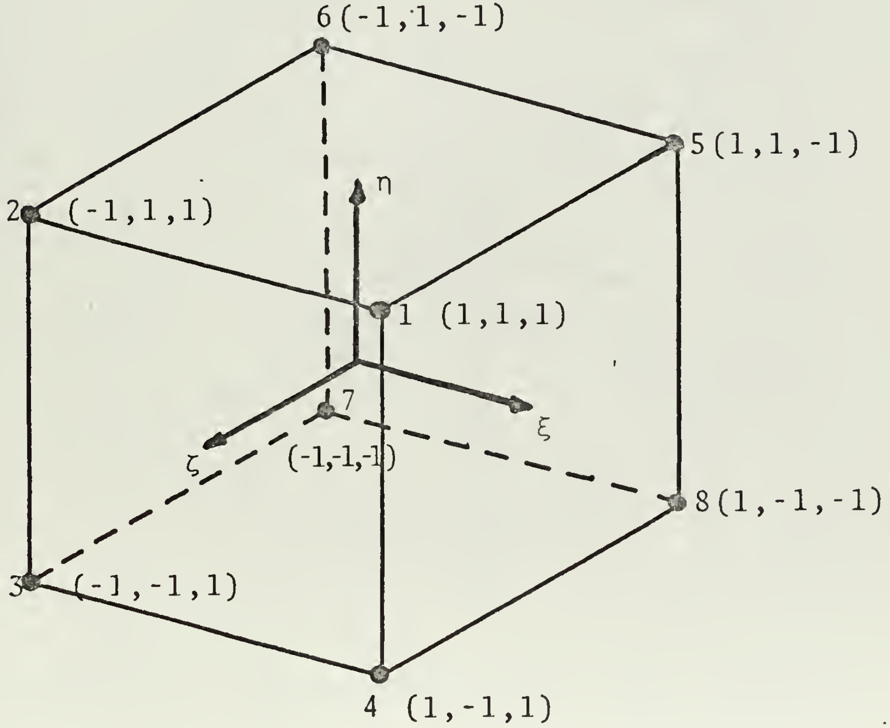


Figure 5. Three-dimensional Linear Element.

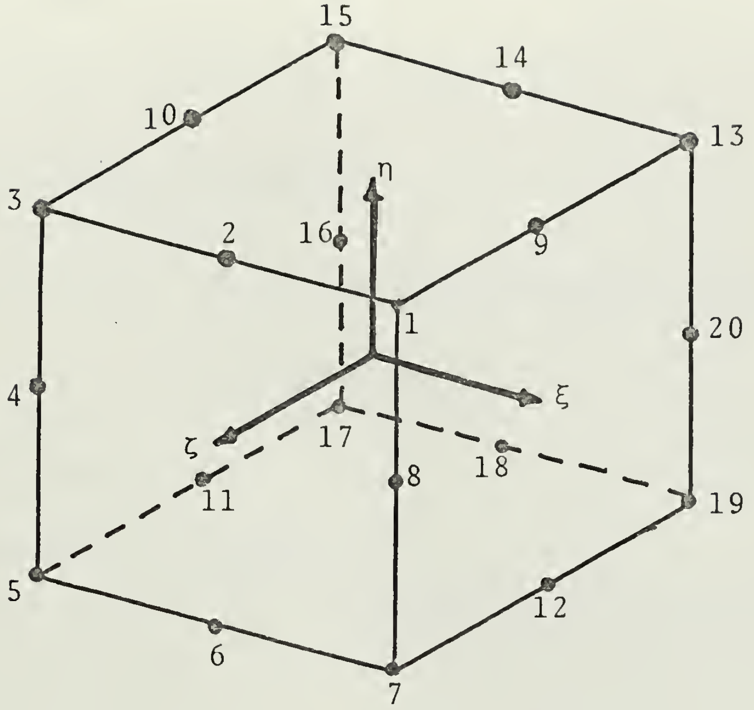


Figure 6. Three-dimensional Quadratic Element.

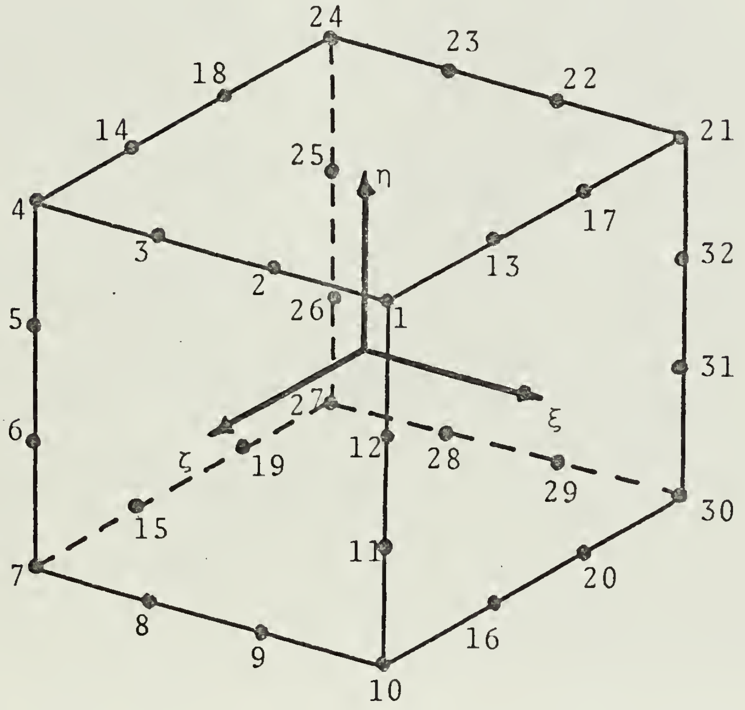


Figure 7. Three-dimensional Cubic Element.

C. SHAPE FUNCTIONS

Let $\xi_o = \xi\xi_i$; $\eta_o = \eta\eta_i$; $\zeta_o = \zeta\zeta_i$

1. Two-Dimensional Elements

a. Linear elements

See Figure 3(a) for identification of the nodes.

$$N_i = (1/4)(\xi_o + 1)(\eta_o + 1) \tag{3}$$

where $\xi_i = \pm 1$ and $\eta_i = \pm 1$.

b. Quadratic elements

See Figure 3(b) for identification of the nodes.

Corner nodes: 1,3,5,7

$$N_i = (1/4)(1+\xi_o)(1+\eta_o)(\xi_o+\eta_o-1) \tag{4}$$

where $\xi_i = \pm 1$ and $\eta_i = \pm 1$.

Side nodes: 2,4,6,8

$$N_i = (1/2)(1 - \xi^2)(1 + \eta_o), \tag{5}$$

for nodes 2 and 6, where $\eta_i = \pm 1$

$$N_i = (1/2)(1 + \xi_o)(1 - \eta^2), \tag{6}$$

for nodes 4 and 8, where $\xi_i = \pm 1$.

c. Cubic elements

See Figure 3(c) for identification of nodes.

Corner nodes: 1,4,7,10

$$N_i = (1/32)(1 + \xi_o)(1 + \eta_o)[9(\xi^2+\eta^2) - 10] \tag{7}$$

where $\xi_i = \pm 1$, $\eta_i = \pm 1$.

Side nodes: 5,6,11,12

$$N_i = (9/32)(1+\xi_o)(1-\eta^2)(1+9\eta_o), \qquad (8)$$

where $\xi_i = \pm1$, $\eta_i = \pm1/3$.

Side nodes: 2,3,8,9

$$N_i = (9/32)(1+\eta_o)(1-\xi^2)(1+9\xi_o), \qquad (9)$$

where $\xi_i = \pm1/3$, $\eta_i = \pm1$.

2. Three-dimensional Elements

a. Linear elements

See Figure 5 for identification of nodes.

$$N_i = (1/8)(1+\xi_o)(1+\eta_o)(1+\zeta_o), \qquad (10)$$

where $\xi_i = \pm1$, $\eta_i = \pm1$, $\zeta_i = \pm1$.

b. Quadratic elements

See Figure 6 for identification of nodes.

Corner nodes: 1,3,5,7,13,15,17,19

$$N_i = (1/8)(1+\xi_o)(1+\eta_o)(1+\zeta_o)(\xi_o+\eta_o+\zeta_o-2) \qquad (11)$$

where $\xi_i = \pm1$, $\eta_i = \pm1$, $\zeta_i = \pm1$.

Side nodes: 2,6,14,18

$$N_i = (1/4)(1-\xi^2)(1+\eta_o)(1+\zeta_o) \qquad (12)$$

where $\xi_i = 0$, $\eta_i = \pm1$, $\zeta_i = \pm1$.

Side nodes: 4,8,16,20

$$N_i = (1/4)(1-\eta^2)(1+\zeta_o)(1+\xi_o) \qquad (13)$$

where $\xi_i = \pm 1$, $\eta_i = 0$, $\zeta_i = \pm 1$

Side nodes: 9,10,11,12

$$N_i = (1/4)(1-\zeta^2)(1+\xi_o)(1+\eta_o) \tag{14}$$

where $\xi_i = \pm 1$, $\eta_i = \pm 1$, $\zeta_i = 0$

c. Cubic elements

See Figure 7 for identification of nodes.

Corner nodes: 1,4,7,10,21,24,27,30

$$N_i = (1/64)(1+\xi_o)(1+\eta_o)(1+\zeta_o)[9(\xi^2+\eta^2+\zeta^2)-19] \tag{15}$$

where $\xi_i = \pm 1$, $\eta_i = \pm 1$, $\zeta_i = \pm 1$

Side nodes: 2,3,8,9,22,23,28,29

$$N_i = (9/64)(1-\xi^2)(1+9\xi_o)(1+\eta_o)(1+\zeta_o) \tag{16}$$

where $\xi_i = \pm 1/3$, $\eta_i = \pm 1$, $\zeta_i = \pm 1$

Side nodes: 5,6,11,12,25,26,31,32

$$N_i = (9/64)(1-\eta^2)(1+9\eta_o)(1+\zeta_o)(1+\xi_o) \tag{17}$$

where $\xi_i = \pm 1$, $\eta_i = \pm 1/3$, $\zeta_i = \pm 1$

Side nodes: 13,14,15,16,17,18,19,20

$$N_i = (9/64)(1-\zeta^2)(1+9\zeta_o)(1+\xi_o)(1+\eta_o) \tag{18}$$

where $\xi_i = \pm 1$, $\eta_i = \pm 1$, $\zeta_i = \pm 1/3$.

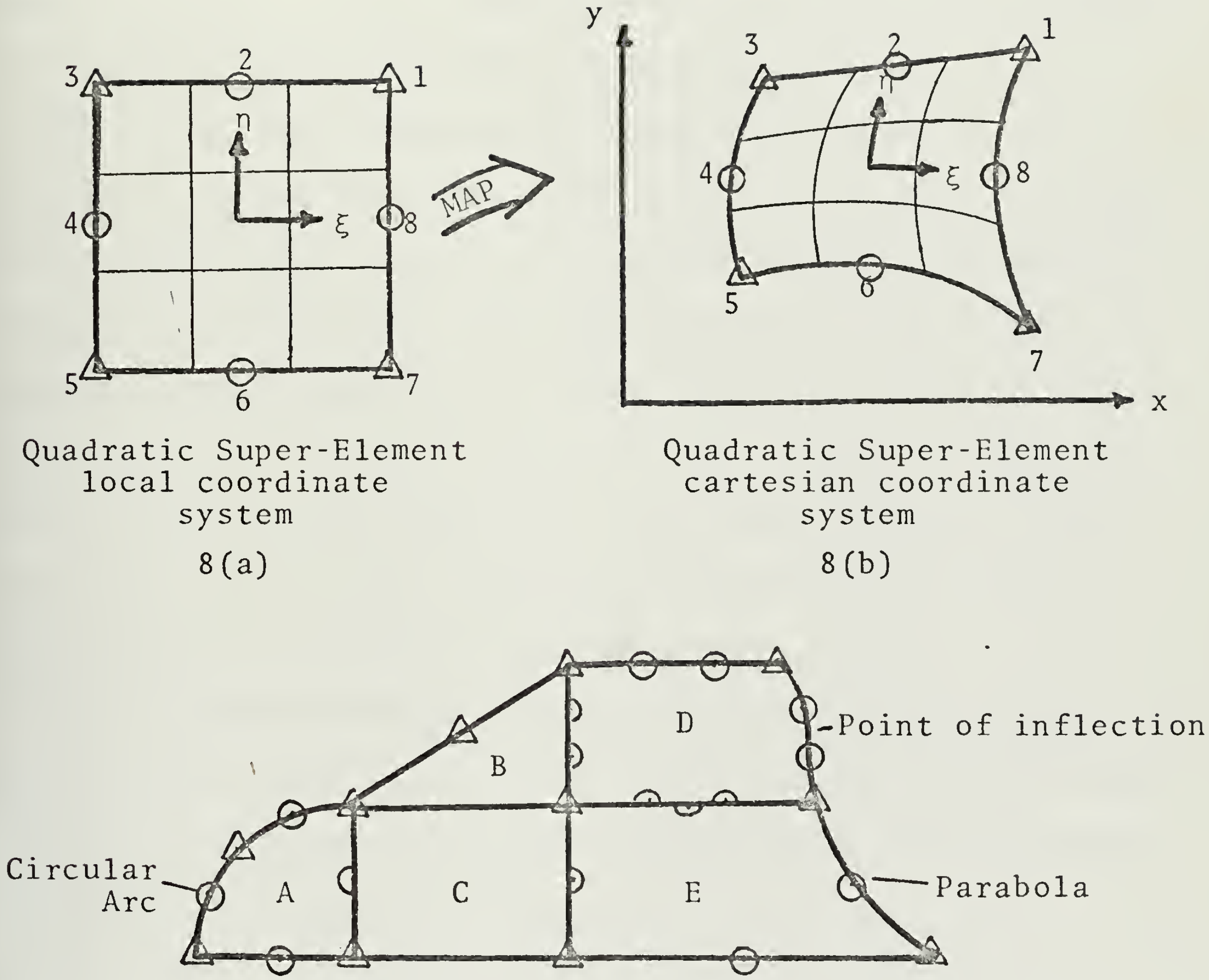
III. BASIS OF AUTOMATIC MESH GENERATION SCHEME

As mentioned in the introduction, reference 3 prompted the utilization of the following scheme in this thesis research.

The essence of the scheme is the use of simple mapping functions to transform simple orthogonal connectivity diagrams into real geometrical shapes. Considering the particular two-dimensional case of a parabolic quadrilateral of Figure 4, in which the x and y co-ordinates of eight nodes are known, we can write equation (1) from Chapter II, where N_i is a shape function associated with each node and defined in terms of a local non-dimensional coordinate system ξ and η which has values ranging from 1 to -1 on opposite sides.

Typical shape functions are given in II.C., and for this example equations (4), (5), and (6) apply. If the co-ordinates of the nodal points are known, then cartesian co-ordinates of any specified point (ξ,η) can be found by equation (1).

If the whole region in which the mesh is to be generated could be described adequately by a quadrilateral of the shape in Figure 4, a mesh of any refinement could be automatically generated inside it by specifying the coordinates of the eight boundary nodal points and the number of sub-divisions in the ξ and η directions. The above scheme is shown pictorially in Figures 8(a) and 8(b).



Quadratic Super-Element local coordinate system

8(a)

Quadratic Super-Element cartesian coordinate system

8(b)

Super-Element Selection

8(c)

Super-Element	Type
A	quadratic
B	linear
C	linear
D	cubic
E	quadratic

△ corresponds to corner nodes

⊙ corresponds to side nodes

◗ corresponds to side nodes for a single Super-Element whose adjacent Super-Element is of a different type

Figure 8

If the whole region could not be adequately described by Figure 4, then we could subdivide the region into more than one quadrilateral and apply the same principles to each as specified above. These region subdivisions will be referred to as Super-Elements hereafter (see Figure 8).

The local Super-Element of Figure 8(a) can be quite drastically distorted, even up to a point of making two sides lie along the same line in the cartesian system such as in a triangle or semi-circle. Care must however be taken not to make any corner angles greater than 180° as a non-uniqueness may result [1]. In addition, side nodes should be equally spaced between corner nodes to insure equal spacing of subdivisions in the ξ and η directions and thus the x and y directions in the mapped cartesian system.

The criteria above also apply to the linear and cubic isoparametric Super-Elements for two-dimensional meshes, and the linear, quadratic and cubic isoparametric Super-Elements for three-dimensional meshes.

The decision on whether to use linear, quadratic or cubic Super-Elements will depend entirely upon the region boundary to be mapped. Linear Super-Elements will map quadrilaterals with straight sides; quadratic Super-Elements will map quadrilaterals with straight or parabolic sides; cubic Super-Elements will map quadrilaterals with straight, parabolic or cubic sides. Figure 8(c) is an illustration of Super-Element selection based upon region (structure) boundary conditions.

The final generated mesh for a given structure may contain nodes on the boundary which do not exactly coincide with the actual structure boundary, or the elements within may not be represented sufficiently accurately. In this case it may be necessary to have some of the coordinates adjusted once the mesh has been generated. This adjustment will be quite easily accomplished with the aid of computer plots, which can be obtained as output to the mesh generating programs discussed in Chapter IV.

IV. DISCUSSION OF COMPUTER PROGRAMS

The computer programs presented in this thesis were written to support the computer systems 'PLISOP' and 'TRISOP', both of which were coded by Professor G. Cantin, and his students of the Naval Postgraduate School, Monterey, California. TRISOP performs a structural analysis of three-dimensional problems using isoparametric finite elements, while 'PLISOP' performs the same analysis of two-dimensional problems. The input data to each system is quite extensive with regard to element connectivity and nodal point coordinates.

The automatic mesh generating systems discussed in this chapter compute the element connectivity and nodal point coordinates required for the above two computer systems. Four mesh generating programs will be discussed. The first generates data for 'PLISOP' with linear, quadratic and cubic elements, and is called 'PLIMEG'. The other three programs generate data for 'TRISOP' with linear, quadratic, and cubic elements respectively. They are called 'TRIMEG-1', 'TRIMEG-2' and 'TRIMEG-3'.

A. THE GENERAL PROGRAM

While a simple mesh generator using only one super-element may be sufficient for some purposes, it is limited to simple geometries with but a single uniform property. For

complete generality, as suggested at the end of Chapter III, the scheme was extended to many super-elements, either linear, quadratic, cubic or any combination of the three, and represented in a 'checkerboard' pattern, where each of the super-elements may be sub-divided and each may define a material with a single property. The above scheme is presented in Sections B and C of this chapter for two and three-dimensional meshes respectively.

B. TWO-DIMENSIONAL MESH GENERATION (PLIMEG)

1. Definitions (see Figure 9)

a. SEL: an acronym, used to refer to a super-element as defined previously on page 7.

b. Master Grid: A 10 x 10 'checker-board' array of SELs which is utilized as a working board for SEL numbering and orientation. The master grid SELs are numbered sequentially along grid columns.

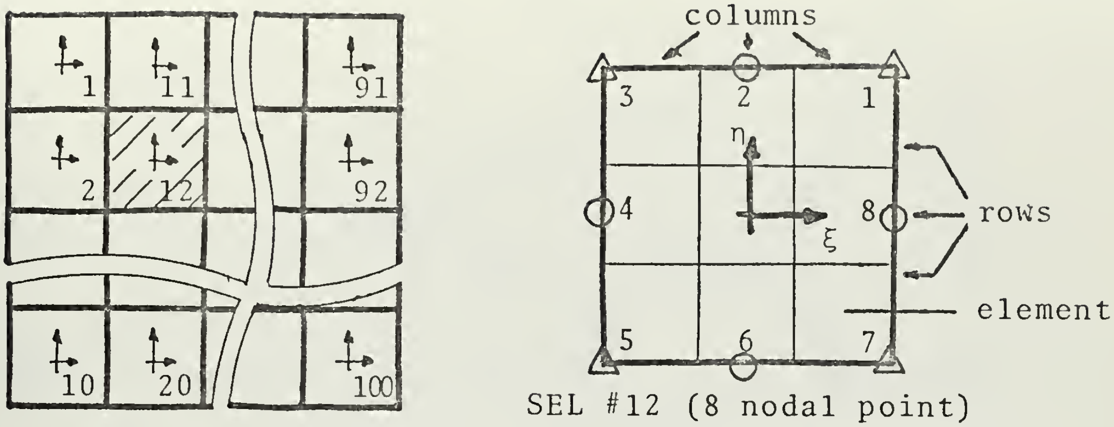
c. Rows: subdivisions of a SEL in η direction

d. Columns: subdivisions of a SEL in ξ direction

e. Elements: those portions of a SEL created by rows and columns

2. Super-element Selection

The number of SELs required in a given mesh is determined from boundary considerations and the types of materials from which the object is composed. Enough SELs must be incorporated to adequately define the boundary of the object, and at least one SEL must be utilized for each different type of material. Figure 10 shows an example for a particular object. The reader will note in Figure 10(a) that the common boundary of SEL 1 and SEL 2 is based on material type,



SEL #12 (8 nodal point)
9(b)

Master Grid
9(a)

△ indicates corner nodes; ⊙ indicates side nodes
All nodes indicated comprise SEL boundary nodes-

Figure 9. PLIMEG Definitions.

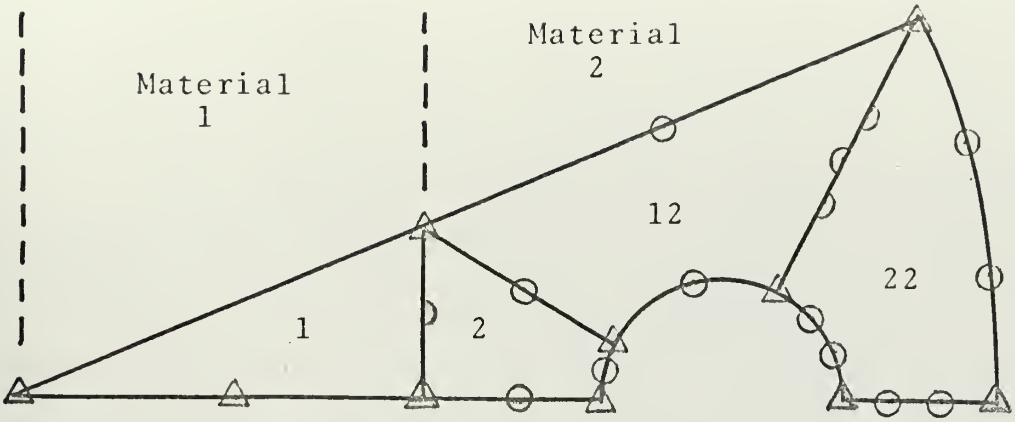
while the remaining boundaries are determined from geometrical considerations only.

Once the quantity and type of SELs have been determined, the proper SEL orientation in the local nondimensional system of reference must be decided upon, as shown in Figure 10(b). The local system is now superimposed upon the master grid of Figure 9 to obtain the SEL numbering scheme of Figure 10(b). Note: this superimposition may be anywhere within the boundary of the master-grid.

3. Mesh Criteria

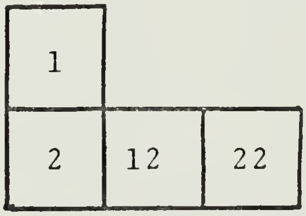
The following rules must be adhered to at all times:

a. All elements within a given mesh must be of the same type (i.e., linear, or quadratic or cubic), and only the type of SEL may vary.



Cartesian SEL Diagram

10(a)



△ corresponds to corner nodes

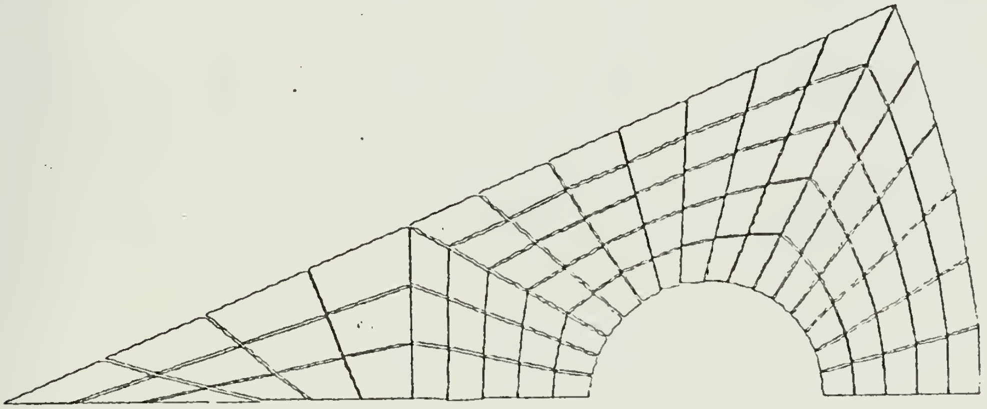
⊙ corresponds to side nodes

Ɖ corresponds to side nodes for a single SEL whose adjacent SEL is of a different type

Local SEL Diagram

10(b)

SEL 1: 4 rows, 3 columns (linear)
SEL 2: 5 rows, 3 columns (quadratic)
SEL 12: 5 rows, 7 columns (quadratic)
SEL 13: 5 rows, 6 columns (cubic)



Final Mesh

10(c)

Figure 10. PLIMEG Example.

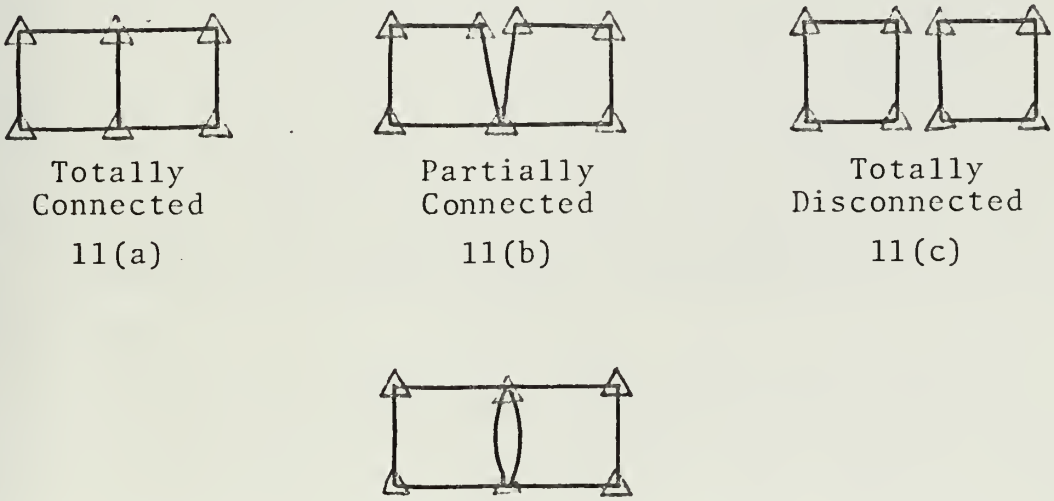
b. The number of rows in all SELs of any master grid row must be equal (i.e., SELs 2,12,22...92).

c. The number of columns in all SELs of any given master grid column must be equal (i.e., SELs 11,12,13...20).

d. SELs may be connected to adjacent SELs in the following ways (see Figure 11): totally connected, connected at one corner only, totally disconnected, and connected at the corner nodes only but not along common edge. Figure 11 shows only horizontally connected SELs, but the same connection schemes apply to vertically connected SELs as well.

4. Bandwidth, Node and Element Numbering

Element numbering is always along master grid columns, and with the exception of discontinuities between adjacent SELs, such as in Figures 11(b) and 11(d), node



Totally Connected
11(a)

Partially Connected
11(b)

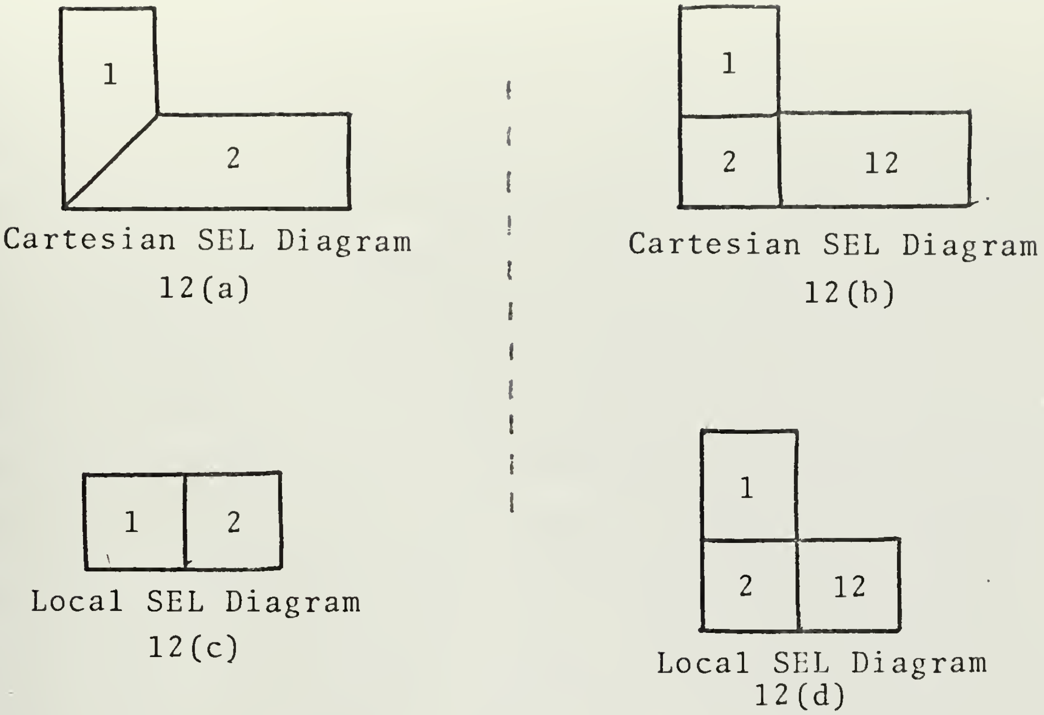
Totally Disconnected
11(c)

Connected at Corner Nodes Only
11(d)

Figure 11. SEL Connections.

numbering is also along master grid columns. Therefore, to obtain a node numbering scheme which results in the best computational efficiency, since 'PLISOP' and 'TRISOP' are designed to be used with a banded stiffness matrix solution, it is prudent that the number of rows in the master grid row containing the most columns be less than or equal to the total number of columns in that particular master grid row. (The reader is referred to Section C.3 of this chapter for additional information regarding this topic.) For example, in Figure 10 the master grid row containing the most columns is grid row two, in which there are sixteen columns, while the number of rows in this grid row is five, thereby satisfying the above criteria for bandwidth. Another example concerning bandwidth is as follows: suppose the object to be considered is in the shape of an "L" and that all SELs contain an equal number of rows and columns (i.e., 3). Two different SEL combinations could be utilized to describe the mesh as shown in Figures 12(a) and 12(b). However it is evident from Figures 12(c) and 12(d) that bandwidth would be greater for the shape of Figure 12(b), since there are six rows in master grid column one for Figure 12(d) vice three for Figure 12(c).

There will be many instances when the geometries of Figure 12 will present itself, and when this condition arises, the user must determine whether element shape within the mesh or a mesh with minimum bandwidth is the more crucial.



Cartesian SEL Diagram 12(a)

Cartesian SEL Diagram 12(b)

Local SEL Diagram 12(c)

Local SEL Diagram 12(d)

Figure 12. The "L" Shape.

Whenever discontinuities such as those of Figures 11(b) and 11(d) exist in a mesh, a good guideline to follow is to have them exist above or below a SEL, if possible, rather than to the left or right, since the latter type of SEL connection occasionally results in a somewhat non-efficient node numbering scheme due to the complicated coding incorporated in Subroutine CONN of PLIMEG.

5. PLIMEG Output

The major portion of the output with PLIMEG is element connectivity and nodal coordinates, however additional output has been incorporated to aid in the use of PLISOP. To begin with, all data input to PLIMEG will be reproduced as output as a check to the user, in event a mispunched data card is experienced. The total number of

elements and joints in the mesh together with the half bandwidth will also be printed. In addition, an option to punch on data cards the element connectivity and coordinates of the joints is incorporated. Lastly, a plot of the mesh may be obtained on the printer, whereby Subroutine GRID calls Subroutine UTPLOT in the IBM 360 source library. However, since plots on the printer are somewhat distorted and only consist of points, a plot can also be obtained on the off-line plotter (Calcomp) whereby Subroutine GRID calls Subroutine DRAW in the source library. The resulting plot is as those shown in Figures 2 and 10(c). The printer plot should be used in determining proper mesh discretization and then Calcomp for the final plot of the mesh. Both plots can not be obtained on the same computer run.

Appendix A discusses input data preparation for PLIMEG while Appendix B discusses sample problems and shows the input/output formats, the node and element numbering schemes, and the resulting plots. These two Appendices may be removed and utilized as an instruction manual for PLIMEG once the contents of this and the previous chapters are comprehended by the user.

C. THREE-DIMENSIONAL MESH GENERATION (TRIMEG)

TRIMEG actually consists of three separate programs: one for each type of element (i.e., linear, quadratic, or cubic). They are called TRIMEG-1, TRIMEG-2, and TRIMEG-3 respectively. However, since the computer scheme and the data input incorporated in these programs is identical, they will be discussed

as one (i.e., TRIMEG). TRIMEG also incorporates many of the ideas of PLIMEG, therefore only the dissimilarities between the two schemes will be presented in this section.

1. Definitions (see Figure 13)

a. Master Grid: a 5x5x5 three-dimensional "checkerboard" array of SELs. The master grid SELs are numbered sequentially along master grid columns in successive master grid slices.

b. Slices: sub-divisions of SEL in ζ direction

c. Element: those portions of a SEL created by rows, columns and slices

2. Mesh Criteria

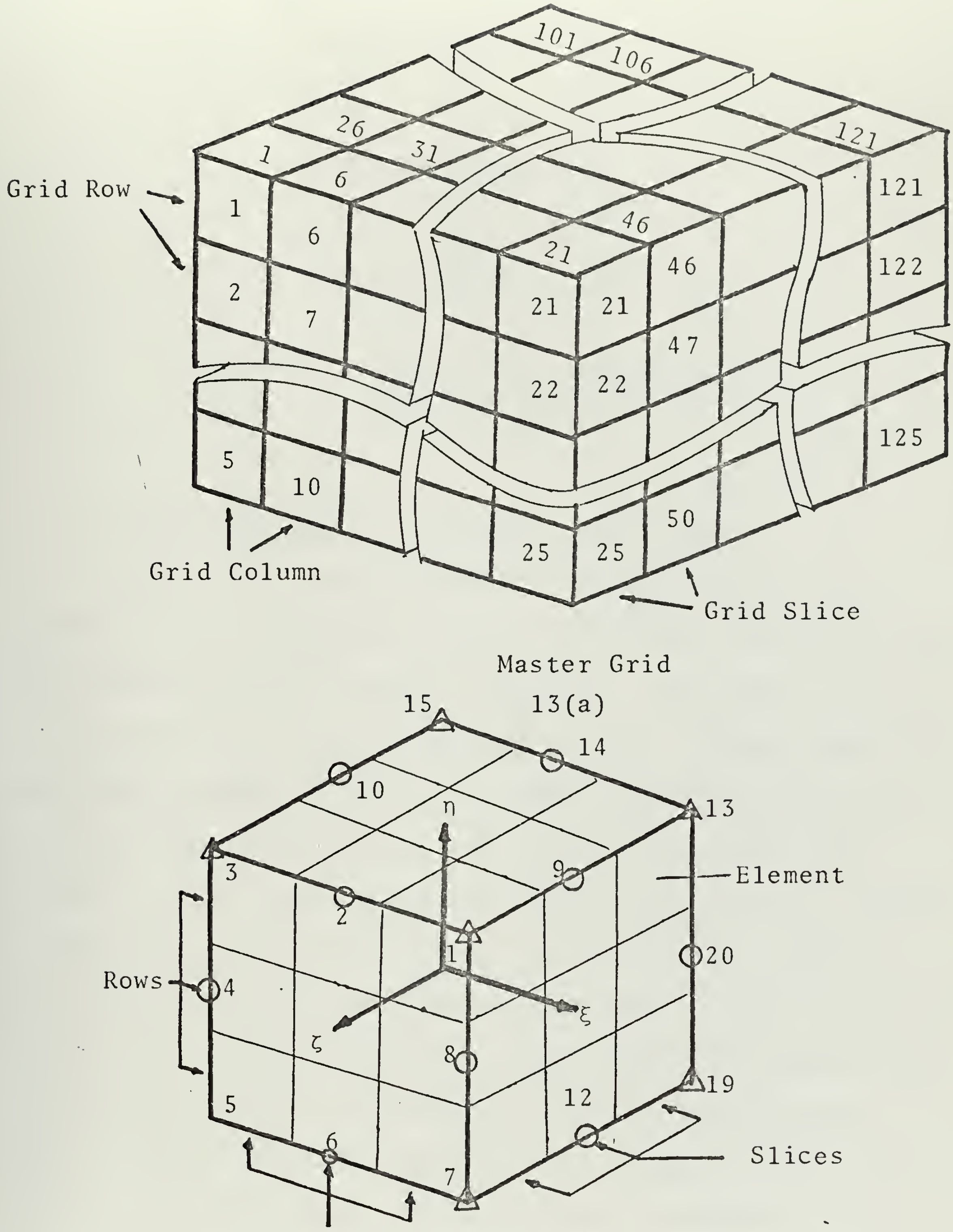
The following rules must be adhered to at all times.

a. The number of rows in all SELs of any master grid row must be equal (i.e., 1,6...21,26,31...46,51,56...71,76,81, ...96,101,106,...121).

b. The number of columns in all SELs of any master grid column must be equal (i.e., 1-5,26-30,51-55,76-80, 101-105).

c. The number of slices in all SELs of any master grid slice must be equal (i.e., 26,27,28...50).

d. The faces of adjacent SELs may be connected in any of the ways shown in Figure 11 (applies to all six faces), with the exception of Figure 11(d). If this situation exists in a mesh, then four SELs must be utilized as shown in Figure 14.



Master Grid

13(a)

SEL #7 (20 nodal points)

13(b)

Figure 13. TRIMEG Definitions.

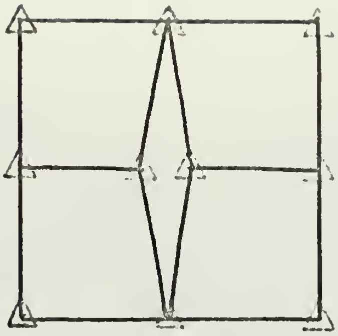
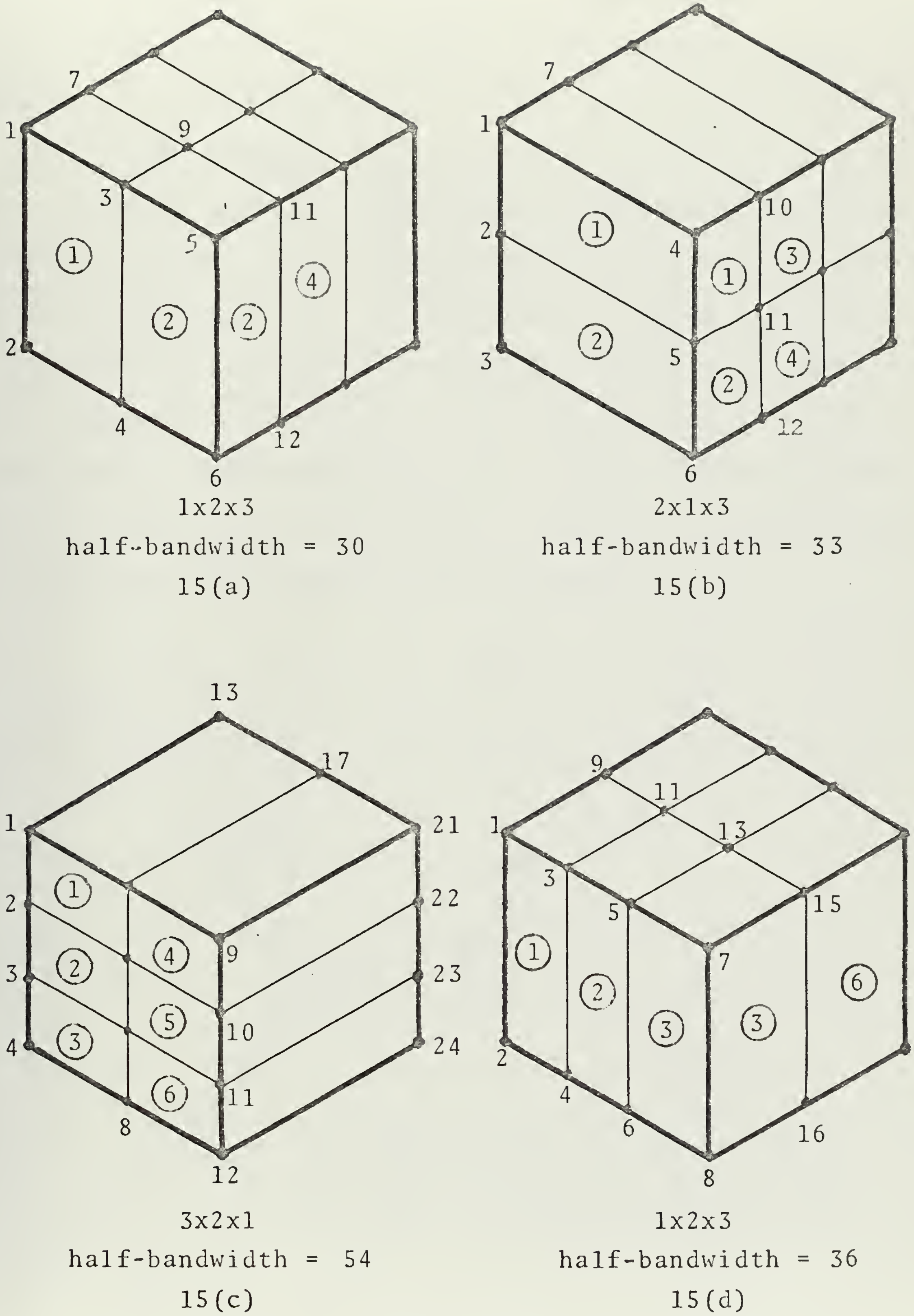


Figure 14. TRIMEG SEL Connection for Similar Connection of Figure 11(a).

3. Bandwidth, Node and Element Numbering

Node and element numbering is identical to that of PLIMEG for each successive slice in the mesh. The following rules apply to obtain minimum bandwidth. The number of rows in the master grid row containing the most columns should be less than or equal to the total number of columns in that particular master grid row. In addition, the number of columns in this master grid row should be less than or equal to the total number of slices in this particular grid row. This scheme can be visualized by sketching a single SEL with one row, two columns and three slices and then numbering the nodes along columns in successive slices. The half-band width is 30 as shown in Figure 15(a). Using two rows, one column and three slices, produces a half bandwidth of 33, etc. The reader should sketch several possibilities for row, column and slice combination (Figure 15) to convince himself that orientation of the mesh determines bandwidth, and thus efficiency, when solving problems with PLISOP and TRISOP. As can be seen in Figure 15, numbering is identical



1x2x3
half-bandwidth = 30
15(a)

2x1x3
half-bandwidth = 33
15(b)

3x2x1
half-bandwidth = 54
15(c)

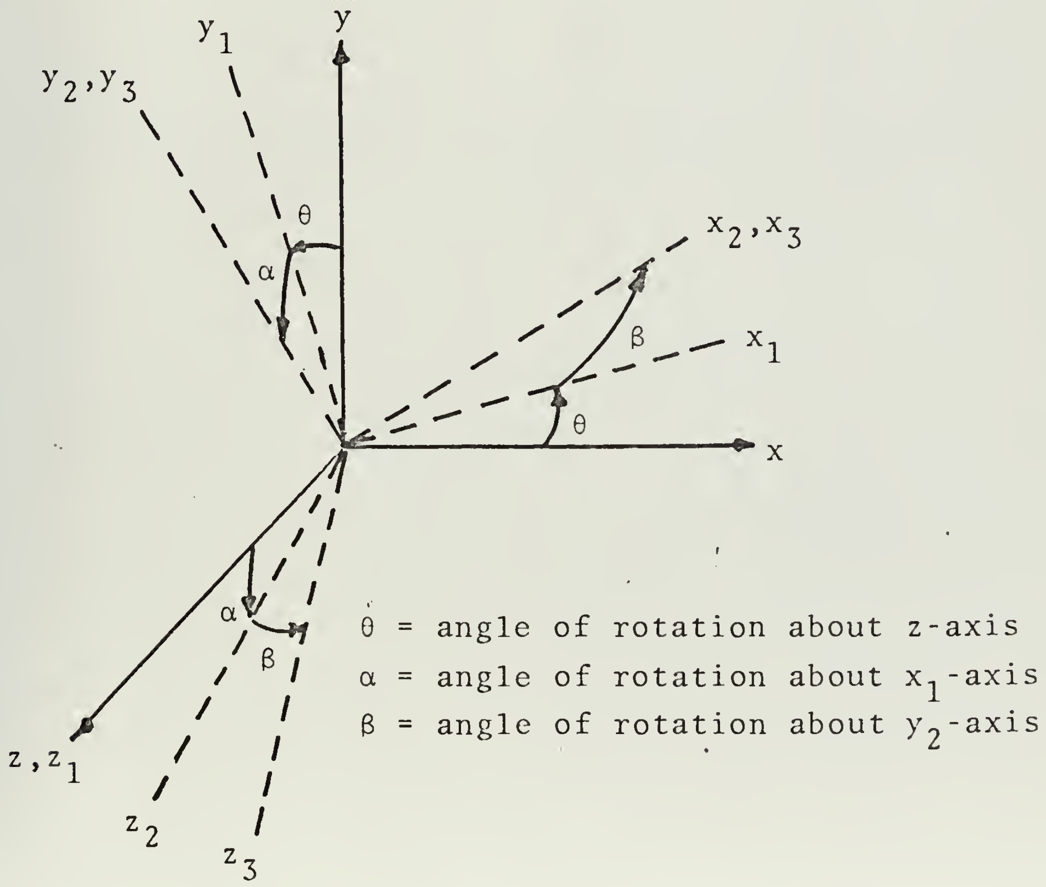
1x2x3
half-bandwidth = 36
15(d)

Figure 15.

to that of PLIMEG for a single SEL with one slice without the third dimension. For PLIMEG the half bandwidth for Figure 15(a) would be 8.

4. TRIMEG Output

TRIMEG output is identical to PLIMEG except for the plotting package. With TRIMEG a plot can only be obtained on the Calcomp plotter. The plots are of three different projections on the planes produced by rotating the mesh about the z-axis, the latest x-axis and the latest y-axis respectively. The three angles of rotation (Euler angles) and the resulting axes are shown in Figure 16 and the scheme is contained in subroutine TRFR of TRIMEG.



θ = angle of rotation about z-axis

α = angle of rotation about x_1-axis

β = angle of rotation about y_2-axis

Figure 16. Axes Rotations for Projection Plotting.

Appendix C discusses input data preparation for TRIMEG while Appendix D discusses sample problems and shows the input/output formats, the node and element numbering schemes, and the resulting plots. These two Appendices may be removed and utilized as an instruction manual for TRIMEG once the contents of this and the previous chapters are comprehended by the user.

V. CONCLUSIONS

The utilization of PLIMEG and TRIMEG automatic mesh generation schemes along with existing finite element programs, now makes it much more practical to solve realistic, complicated problems, since the amount of input data has been reduced as much as 95 per cent. This decrease in the amount of input data cards required for the finite element programs not only reduces the chance for error, but makes problem solving more of a challenge and not just a headache.

VI. RECOMMENDATIONS

PLOT OF STRUCTURE MESH

In addition to the present plotting routine incorporated in TRIMEG, it would be desirable to obtain a plot of the generated mesh which did not contain hidden lines. Professor Gilles Cantin of the Naval Postgraduate School, Monterey, California is presently working on such a solution. Adding the actual node numbers to the computer produced plots would also be of great value.

APPENDIX A

INPUT DATA PREPARATION FOR 'PLIMEG'

```
C
C                                 'PLIMEG'
C
C**********************************************************************
C*                   MESH GENERATING PRCGRAM FOR 'PLISOP'             *
C**********************************************************************
C*    CCDED BY J.R.ADAMEK, DECEMBER 1972, NAVAL PCST GRADLATE SCHCCL   *
C**********************************************************************
C
C        THE NECESSARY INPUT FOR THIS PROGRAM IS AS FOLLCWS:
C
C   CARC 1 AND 2, TITLE, FCRMAT (6A8) EACH CARD.
C
C      CCL. 1 TO 48    BRIEF TITLE OF PRCBLEM. USER'S NAME AND/OR BCX NC.
C                      MUST BE INCLUDED CN ONE OF THE CARDS IF CALCOMP
C                      OPTION INCLUDED. (SEE CARD 3)
C
C
C   CARD 3, MESH PARAMENTERS, FORMAT (4I5).
C
C      COL. 1 TO  5    (NSEL):  NUMBER OF SUPER ELEMENTS.
C
C           6 TO 10    (NPT):   THE NUMBER OF NODAL PCINTS PER ELEMENT.
C                      NPT= 4,8 OR 12
C
C          11 TO 15    (NPUNCH): IF THIS IS ZERO OR BLANK, NC CARDS WILL
C                      BE PUNCHED. IF NPUNCH IS DIFFERENT FROM ZERO A DECK
C                      FOR CONNECTIVITY AND X,Y CCCRDINATES CF ALL JCINTS
C                      WILL BE PUNCHED. NPUNCH BLANK CR ZERO SHCULD ALWAYS
C                      BE USED UNTIL ONE IS SATISFIED WITH THE MESH.
C
C          16 TO 20    (NPLOT):  IF THIS IS ZERO CR BLANK, NC PLOTS WILL
C                      BE MADE. IF NPLOT IS (1) A PLOT WILL BE OBTAINED ON
C                      THE PRINTER(UTPLOT). IF NPLCT IS (2) A PLCT WILL BE
C                      OBTAINED ON CALCOMP PLOTTER.
C                      NPLOT SHOULD BE (1) UNTIL SATISFIED WITH MESH.
C                      ALL PLOTS WILL BE PLOTTED IN FIRST QUADRANT ONLY.
C
C
C   SUPER ELEMENT DECK, TOTAL OF NSEL CARDS, FORMAT (10I5), LOAD IN
C                 ASCENDING ORDER OF SUPER ELEMENT NUMBERS.
C
C      COL. 1 TO  5    (SEL NC.) SUPER ELEMENT IDENTIFICATICN NUMBER.
C
C           6 TC 10    (ROW):   NUMBER CF ROWS IN SUPER ELEMENT.
C
C          11 TO 15    (COL):   NUMBER OF COLUMNS IN SUPER ELEMENT.
C
```

```
C         16 TO 20   (NODE  A):    *************************************
C                                  *                          A     C   *
C         21 TO 25   (NODE  B):    *     SUPER ELEMENT         *****    *
C                                  *      CCNNECTIVITY         *   *    *
C         26 TO 30   (NODE  C):    *    COUNTERCLCCKWISE       *   *    *
C                                  *       (SEE NCTE)          *****    *
C         31 TO 35   (NODE  D):    *                          B     C   *
C                                  *************************************
C
C                    NOTE: NUMBERING OF SUPER-ELEMENT CCRNER NODES IS
C                    ARBITRARY. HOWEVER, CORNER NCDES WHICH ARE
C                    CONNECTED TO CTHER CCRNER NCCES, MUST HAVE
C                    THE SAME NUMBER.
C
C         36 TO 40   (TYPE):   MATERIAL ICENTFICATICN NUMBER FOR
C                              SUPER ELEMENT.(SEE 'PLISOP' INST)
C
C         41 TO 45   (NPTSB):  NUMBER OF SUPER ELEMENT BCUNCARY NODES.
C                              NPTSB = 4,8 OR 12
C
C         46 TO 50   (CON):    IF SUPER ELEMENT IS CCNNECTED TO AN
C                              ADJACENT SUPER ELEMENT BELCW OR TO THE
C                              RIGHT ONLY AT THE CCRNER NODES AND NOT IN
C                              BETWEEN, ENTER ADJACENT SUPER ELEMENT
C                              NUMBER HERE. OTHERWISE LEAVE BLANK.
C
C
C   SUPER ELEMENT BOUNDARY DECK, TOTAL CF NPTB CARDS,   (3I5,2G25.17)
C
C                 NPTB=SUM CF BOUNDARY NODES OF ALL SUPER ELEMENTS.
C                 ORDER IS COUNTER CLOCK-WISE STARTING AT NODE CCMMON
C                 WITH (XI,ETA)=(1,1). IF MORE THAN CNE SUPER ELEMENT,
C                 LOAD ITS BOUNDARY AFTER THAT OF FIRST SUPER ELEMENT
C                 IN SAME NODAL ORDER AS ABOVE. CRCER OF SUPER ELEMENTS
C                 SAME AS FOR SUPER ELEMENT DECK.
C
C      CCL. 1 TO  5   (SEL NO.):  SUPER ELEMENT ICENTIFICATION NUMBER.
C
C           6 TO 10   (NODE NO.): ARBITRARY NUMBERING OF SUPER ELEMENT
C                                 BOUNCARY NODES. MAY OR MAY NOT BE THE
C                                 SAME NUMBERING SCHEME AS
C                                 FOR CCNNECTIVITY.
C
C          11 TO 15   (NCT):    TYPE OF COORDINATES. IF THIS FIELD IS
C                     BLANK OR ZERO, CARTESIAN CCCRDINATES ARE USED.
C                     IF NCT IS (1), THE X COORDINATE IS INTERPRETEC
C                     AS THE RADIUS VECTCR AND THE Y COORDINATE AS THE
C                     POLAR ANGLE IN DEGREES WITH CENTER OF CURVATURE
```

```
C                    AT THE ORIGIN. NCT = (2) CR (3) IS INTERPRETEC THE
C                    SAME AS FOR NCT=(1), EXCEPT CENTER OF CURVATURE
C                    NOT AT THE ORIGIN. IF NCT IS (2), A NEW DATA CARD
C                    IS INSERTED AFTER PRESENT CNE. ONLY REQUIRED FCR
C                    FIRST NODE WITH THIS PARTICULAR CENTER OF
C                    CURVATURE. ** FORMAT (2G25.17) **
C
C                    COL. 1 TO 25  X COORD. OF CENTER OF CURVATURE
C
C                        26 TO 50  Y COORD. OF CENTER OF CURVATURE.
C
C                    NCT IS (3) FOR CENTER OF CURVATURE NOT AT ORIGIN
C                    FOR REMAINING NODES WITH THIS PARTICULAR CENTER
C                    OF CURVATURE. NCT IS (4) FCR MID SIDE NODE OF EIGHT
C                    NODAL BOUNDARY WITH PARTICULAR SIDE LINEAR. NCT IS
C                    (5) FOR MID SIDE NCDE OF TWELVE NODAL BOUNDARY
C                    WITH PARTICULAR SIDE LINEAR.. LOAD ZERO OR BLANK
C                    FOR X AND Y COORDINATES WHEN NCT IS (4) CR (5).
C
C         16 TO 40   X COORDINATE OF NCDE, REAL*8
C
C         41 TO 65   Y COORDINATE OF NODE, REAL*8
C
C     ADDITIONAL PROBLEMS MAY ALSO BE LCADED AFTER FIRST PROBLEM.
C
C     STORAGE REQUIREMENTS ARE AS FOLLOWS:
C     130K FCR NO PLOT AND PLOTP; 150K FCR CALCCMP.
C       REPRESENTATIVE EXAMPLES USING AROUND EIGHT SUPER ELEMENTS
C       EXECUTED IN APPROXIMATELY 30 SECCNDS.
C
C***********************************************************************
C
C
```

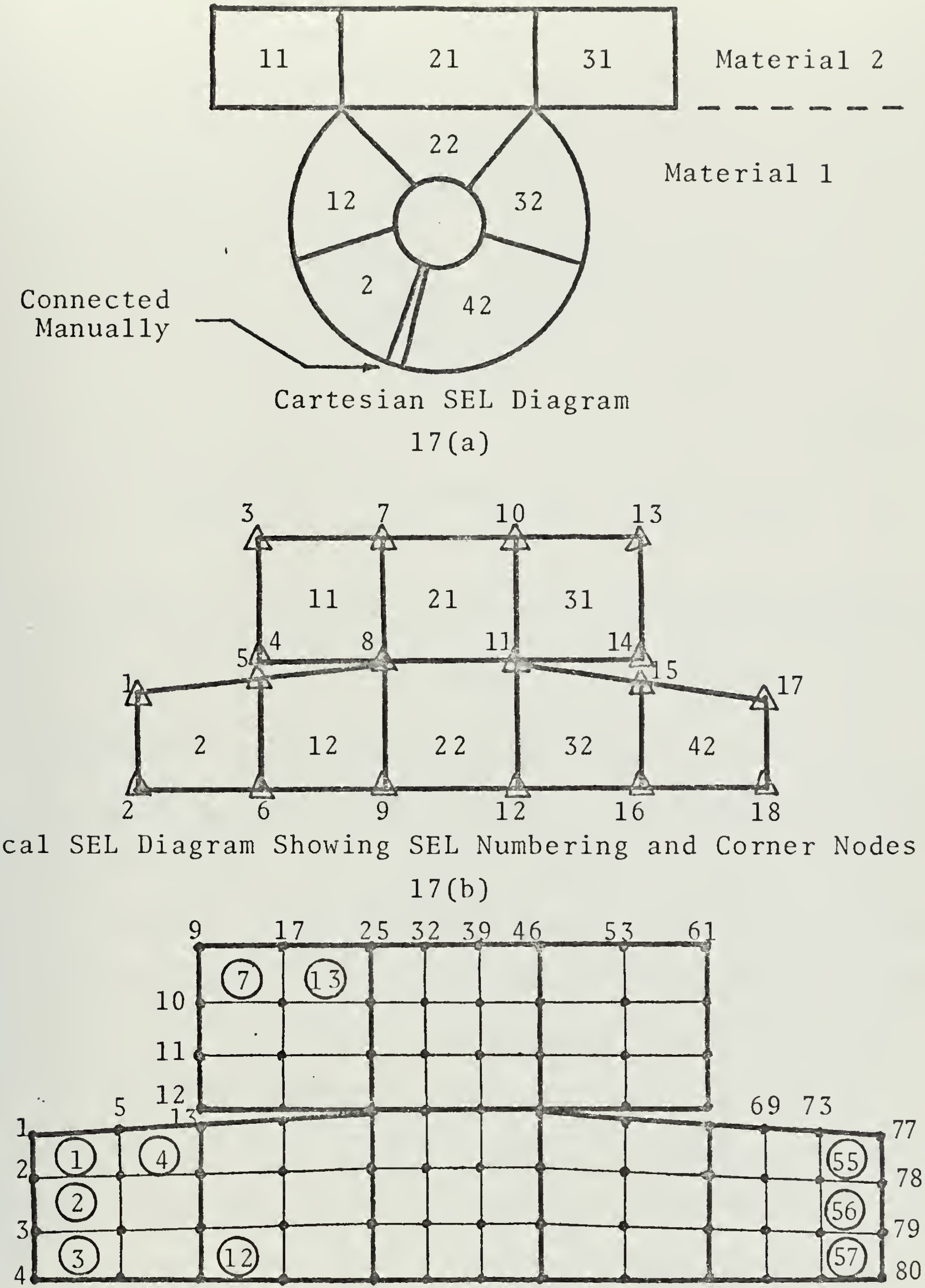
APPENDIX B

PLIMEG EXAMPLES, INPUT AND OUTPUT

This appendix discusses two example problems. The first will show SEL selection and connection procedures dealing with an eight SEL object with discontinuities along some edges, and also the node and element numbering schemes incorporated in PLIMEG. The second will be a more straightforward example illustrating the detail of input data and output formats.

A. EXAMPLE ONE (Padeye; see Figures 17 and 18)

The common boundary of SEL 21 and SEL 22 is based on material type, while the remaining SEL boundaries are determined from geometrical considerations only. As noted in Figure 17(a), the common boundary of SEL 2 and SEL 42 must be connected manually once the mesh has been generated. This is accomplished as follows (see Figure 17(c)). The final mesh of Figure 18 will not contain nodes 77-80, therefore remove these nodes from the output punched deck of coordinates and change the element connectivity cards for elements 55,56 and 57. In other words, node 77 becomes node 1, node 78 becomes node 2, node 79 becomes node 3 and node 80 becomes node 4. The number of nodal points (joints) will now be 76 vice 80, while the number of elements will remain the same (i.e., 56). Half bandwidth will be increased from 20 to 148, but may be held to 50 if SELs 1,2,3,4,5,12,13 and 14, for example, are used to describe the mesh.



Cartesian SEL Diagram

17(a)

Local SEL Diagram Showing SEL Numbering and Corner Nodes

17(b)

Subdivided Local SEL Diagram Showing Node and Element Numbering (linear element)

17(c)

Figure 17.

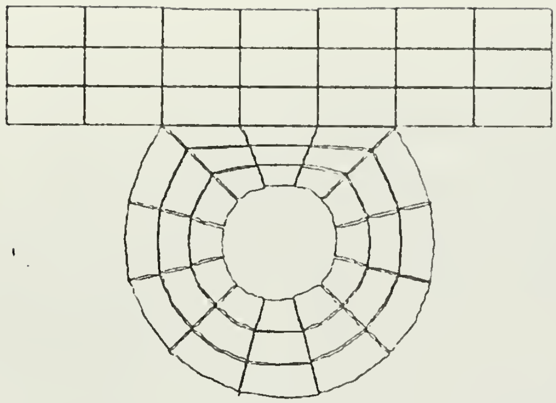


Figure 18. Final Mesh for Example One.

The remaining variables for input to PLIMEG will be shown in the more straightforward example which follows.

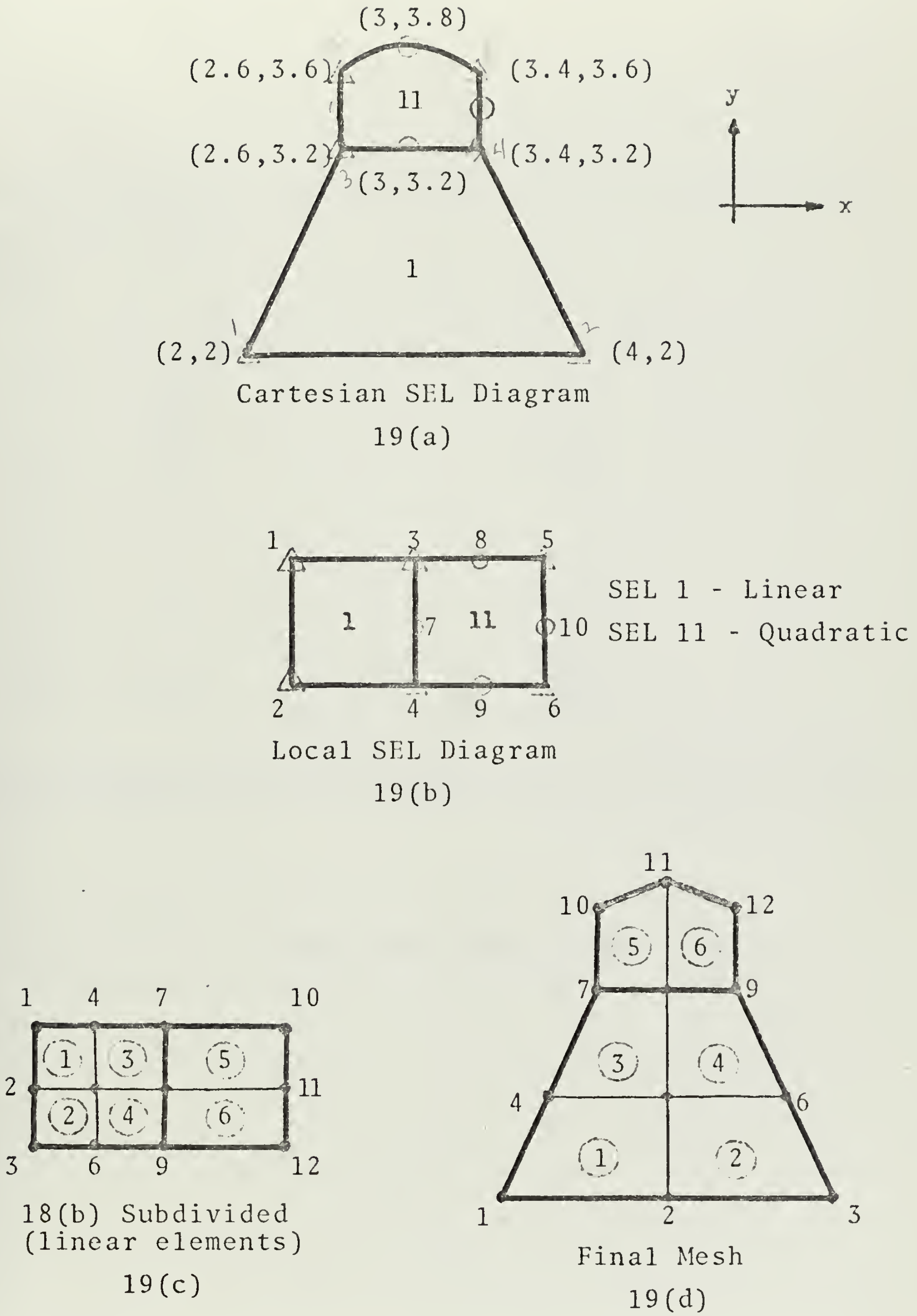
B. EXAMPLE TWO (See Figures 19, 20 and 21)

Figure 19 shows a simplified mesh generation scheme consisting of two SELs, six elements (linear) and 12 nodal points (joints). Although SELs connected vertically could have been utilized, this would have established a mesh with three rows and two columns resulting in a half-bandwidth greater than that of the existing mesh.

Although the mesh is quite coarse, it adequately describes the data input for the given boundary situation. The SELs could have been subdivided to produce a much finer mesh, however the amount of input data would remain unchanged.

Figure 20 shows in detail the input and input format required for PLIMEG as described in Appendix A, while Figures 21 and 22 present the output and output format. The last

two columns of the connectivity matrix (Figure 22) are KIND and TYPE. These quantities represent the kind of element and the type of material for that element, respectively. KIND equal to one implies linear elements, two implies quadratic, and three implies cubic. This information is required input for PLISOP.



Cartesian SEL Diagram
19(a)

Local SEL Diagram
19(b)

18(b) Subdivided
(linear elements)
19(c)

Final Mesh
19(d)

Figure 19. Example Two.

```
123456789012345678901234567890123456789012345678901234567890

PLIMEG**EXAMPLE TWO**
J.R.ADAMEK
    2    4    0    0
    1    2    2    1    2    4    3   1     4
   11    2    1    3    4    6    5   1     8
    1    3     2.6                     3.2
    1    1     2.0                     2.0
    1    2     4.0                     2.0
    1    4     3.4                     3.2
   11    5     2.6                     3.6
   11    8    4
   11    3     2.6                     3.2
   11    7    4
   11    4     3.4                     3.2
   11    9    4
   11    6     3.4                     3.6
   11   10    20.6                     90.0
3.0                      3.2

123456789012345678901234567890123456789012345678901234567890
```

Figure 20. PLIMEG Input Data (example two).

```
PLIMEG**EXAMPLE TWO**
J.R.ADAMEK


MESH PARAMETERS

          NSEL    NPT   NPUNCH    NPLOT

            2      4       0        0


SUPER ELEMENT DATA

         SEL NO.        ROW    COL    (A)    (B)    (C)    (D)   TYPE   NPTSB   CON

            1             2      2      1      2      4      3     1       4      0
           11             2      1      3      4      6      5     1       8      0


BOUNDARY DATA

   SEL NO.   NODE NO.   NCT          X COORDINATE                   Y COORDINATE


       1          3       0       2.6000000000000000               3.2000000000000000
       1          1       0       2.0000000000000000               2.0000000000000000
       1          2       0       4.0000000000000000               2.0000000000000000
       1          4       0       3.4000000000000000               3.2000000000000000
      11          5       0       2.6000000000000000               3.6000000000000000
      11          8       4      0.0                              0.0
      11          3       0       2.6000000000000000               3.2000000000000000
      11          7       4      0.0                              0.0
      11          4       0       3.4000000000000000               3.2000000000000000
      11          9       4      0.0                              0.0
      11          6       0       3.4000000000000000               3.6000000000000000
      11         10       2      0.6000000000000000               90.000000000000000
                                                  CENTER OF CURVATURE
                                  3.0000000000000000               3.2000000000000000
```

Figure 21. PLIMEG Output (input data check).

```
NUMBER CF ELEMENTS=   6
NUMBER CF JCINTS=  12

CCNNECTIVITY MATRIX
ELEMENT NUMBER                                                                                    KIND TYPE

      1                  4     1     2     5     0     0     0     C     0     C     0     0     1     1
      2                  5     2     3     6     0     0     0     0     0     C     0     C     1     1
      3                  7     4     5     8     0     C     0     C     0     C     0     0     1     1
      4                  8     5     6     9     C     0     0     C     0     C     0     C     1     1
      5                 1C     7     8    11     0     0     0     C     0     0     0     C     1     1
      6                 11     8     9    12     0     C     C     C     0     C     0     0     1     1

HALF BANC WICTH FCR PLISCP STIFFNESS MATRIX=   10

CCCRDINATES CF JCINTS
JCINT NUMEER           X CCCRDINATE     Y COCRDINATE

      1                   2.CCCC           2.00C0
      2                   3.C0C0           2.0000
      3                   4.CCCC           2.0000
      4                   2.3CC0           2.60C0
      5                   3.0CC0           2.6000
      6                   3.7CCC           2.6CC0
      7                   2.6000           3.2C00
      8                   3.CCC0           3.2000
      9                   3.4CCC           3.2CC0
     10                   2.6000           3.60C0
     11                   3.0CC0           3.80C0
     12                   3.4CCC           3.60C0
```

Figure 22. PLIMEG Output.

APPENDIX C

INPUT DATA PREPARATION FOR 'TRIMEG'

```
C
C                                 'TRIMEG'
C
C***********************************************************************
C*                    MESH GENERATING PRCGRAM FOF 'TRISOP'            *
C***********************************************************************
C*      CCDED BY J.R.ADAMEK, APRIL 1973, NAVAL PCST GRADUATE SCHOOL    *
C***********************************************************************
C
C        THE NECESSARY INPUT FOR THIS PROGRAM IS AS FOLLOWS:
C
C  CARC 1 AND 2, TITLE, FORMAT (6A8) EACH CARD.
C
C     CCL. 1 TC 48    BRIEF TITLE OF PROBLEM. USER'S NAME AND/OR BCX NO.
C                     MUST BE INCLUDED CN ONE OF THE CARDS IF CALCOMP
C                     OPTICN INCLUDED. (SEE CARC 3)
C
C  CARC 3, MESH PARAMENTERS, FORMAT (3I5,3F5.0)
C
C     CCL. 1 TC  5    (NSEL):  NUMBER OF SUPER ELEMENTS.
C
C          6 TO 10    (NPUNCH): IF THIS IS ZERO CR BLANK, NC CARDS WILL
C                     BE PUNCHED. IF NPUNCH IS DIFFERENT FRCM ZERO A DECK
C                     FOR CONNECTIVITY AND X,Y & Z CCORDINATES CF JCINTS
C                     WILL BE PUNCHED. NPUNCH BLANK CR ZERO SHOULD ALWAYS
C                     BE USED UNTIL ONE IS SATISFIED WITH THE MESH.
C
C         11 TO 15    (NPLCT):  IF THIS IS ZERO CR BLANK, NO PLOTS WILL
C                     BE MADE. IF NPLOT IS (1) A PLCT WILL EE CBTAINEC ON
C                     THE CALCOMP PLOTTER.
C                     ALL PLOTS WILL BE PLOTTED IN FIRST QUADRANT ONLY.
C
C       . THE FOLLCWING THREE INPUT VARIABLES ARE THE EULER ANGLES.
C         NOT REQUIRED UNLESS NPLOT = 1.
C
C         16 TO 20    (TETA):   ANGLE OF ROTATICN ABCUT Z-AXIS.
C
C         21 TO 25    (ALPHA):  ANGLE OF ROTATICN ABCUT LATEST X-AXIS.
C
C         26 TC 30    (BETA):   ANGLE OF ROTATION ABOUT LATEST Y-AXIS.
C
C  SUPER ELEMENT DECK, TOTAL OF NSEL CARDS, FORMAT (14I5), LCAD IN
C                      ASCENDING ORDER CF SUPER ELEMENT NUMBERS.
C
C     CCL. 1 TO  5    (SEL NO.) SUPER ELEMENT IDENTIFICATICN NUMBER.
C
C          6 TC 10    (RCW):    NUMBER CF ROWS IN SUPER ELEMENT.
```

```
C
C         11 TO 15  (COL):    NUMBER OF COLUMNS IN SUPER ELEMENT.
C
C         16 TO 20  (SLICE):  NUMBER OF SLICES IN SUPER ELEMENT.
C
C
C                             *****************************************
C                             *                          E          H *
C         21 TO 25  (NODE A)  *   SUPER ELEMENT           **********  *
C                             *    CCNNECTIVITY         *       *  *  *
C         26 TO 30  (NODE B)  *  COUNTERCLOCKWISE    *        *    *  *
C                             *     (SEE NOTE)    *        *       *  *
C         31 TO 35  (NODE C)  *                *        *          *  *
C                             *             *        *             *  *
C         36 TO 40  (NODE D)  *       A  *       D *               *  *
C                             *        **********                  *  *
C         41 TO 45  (NODE E)  *        *        *        F      *   G *
C                             *        *        *             *       *
C         46 TO 50  (NODE F)  *        *        *          *          *
C                             *        *        *       *             *
C         51 TO 55  (NODE G)  *        *        *     *               *
C                             *        *        *  *                  *
C         56 TO 60  (NODE H)  *        **********                     *
C                             *       B          C                    *
C                             *****************************************
C
C                   NOTE: NUMBERING OF SUPER-ELEMENT CCRNER NCDES IS
C                   ARBITRARY. HOWEVER, CORNER NCDES WHICH ARE
C                   CCNNECTED TO CTHER CCRNER NCCES, MUST HAVE
C                   THE SAME NUMBER.
C
C         61 TO 65  (TYPE):  MATERIAL ICENTFICATICN NUMBER FCR
C                            SUPER ELEMENT.(SEE 'TRISOP' INST)
C
C         66 TC 70  (NPTSB): NUMBER CF SUPER ELEMENT BCUNCARY NODES.
C                            NPTSB = 8,20 OR 32
C
C
C  SUPER ELEMENT BOUNDARY DECK, TOTAL CF NPTB CARDS,   (3I5,3F20.0).
C
C                NPTB=SUM CF BOUNCARY NCCES OF ALL SUPER ELEMENTS.
C                ORDER IS COUNTER CLOCK-WISE ABCUT ZETA AXIS, STARTING
C                AT NODE CCMMON WITH (XI,ETA,ZETA)=(1,1,1). IF MORE THAN
C                ONE SUPER ELEMENT, LCAD ITS BCUNCARY AFTER THAT OF
C                FIRST SUPER ELEMENT IN SAME NCCAL ORDER AS ABOVE. CRDER
C                OF SUPER ELEMENTS SAME AS FOR SUPER ELEMENT CECK.
C
```

```
C      CCL. 1 TO  5   (SEL NO.):  SUPER ELEMENT IDENTIFICATION NUMBER.
C
C           6 TO 10   (NODE NC.): ARBITRARY NUMBERING OF SUPER ELEMENT
C                                 BOUNDARY NODES. MAY OR MAY NCT BE THE
C                                 SAME NUMBERING SCHEME AS
C                                 FCR CONNECTIVITY.
C
C          11 TC 15   (NCT):    TYPE CF COORDINATES. IF THIS FIELD IS
C                     BLANK OR ZERO, CARTESIAN CCCRDINATES ARE LOACEC
C                     IN FORMAT DESCRIBED BELOW. NCT=(1) FOR MIC SIDE
C                     NODE OF QUADRATIC SUPER ELEMENTS WITH PARTICULAR
C                     SIDE LINEAR. NCT=(2) FOR MIC SIDE NODES CF CUBIC
C                     SUPER ELEMENTS WITH PARTICULAR SIDE LINEAR. LCAD
C                     ZERC OR BLANK FOR X,Y AND Z COORDINATES WHEN NCT
C                     IS (1) OR (2).
C
C          16 TO 35   X CCCRDINATE CF NCCE, REAL*8
C
C          36 TO 55   Y CCCRDINATE OF NOCE, REAL*8
C
C          56 TO 75   Z CCCRDINATE OF NOCE, REAL*8
C
C      ADDITIONAL PRCBLEMS MAY ALSO BE LCACED AFTER FIRST PROBLEM.
C
C      STCRAGE REQUIREMENTS ARE AS FOLLOWS:
C        150K FCR NO PLCT; 170K FOR CALCCMP.
C        REPRESENTATIVE EXAMPLES USING ARCUND EIGHT SUPER ELEMENTS
C        EXECUTED IN APPRCXIMATELY 50 SECCNDS.
C
C*************************************************************************
C
```

APPENDIX D

TRIMEG EXAMPLES, INPUT AND OUTPUT

Since the concept for TRIMEG is very similar to that of PLIMEG, only the figures illustrating two examples will be shown in this appendix. The user should be completely familiar with the contents of Appendix B (PLIMEG Examples, Input and Output) prior to utilizing this appendix and Appendix C (TRIMEG Input Data Preparation).

A. EXAMPLE ONE (Crack Propagation Problem)

Figure 23 shows the local SEL diagram indicating SEL numbers and SEL corner node numbering. The cartesian SEL diagram is not shown since it would be identical to that of the local diagram since the object is a cube. Figure 24 shows the final mesh, where each SEL contains 2 rows, 2 columns and 2 slices.

Example two will completely illustrate all input, output and respective diagrams.

B. EXAMPLE TWO (Folded Plate)

Figures 25, 26 and 27 show a simplified mesh generation scheme consisting of three SELs, 27 elements (linear) and eighty nodal points (joints). Although the mesh is quite coarse, it adequately describes the data input for the given boundary situation.

Figure 28 shows in detail the input and input format required for TRIMEG as described in Appendix C, while Figures 29 and 30 present the output and output format.

Each SEL contains one row, three columns and three slices.

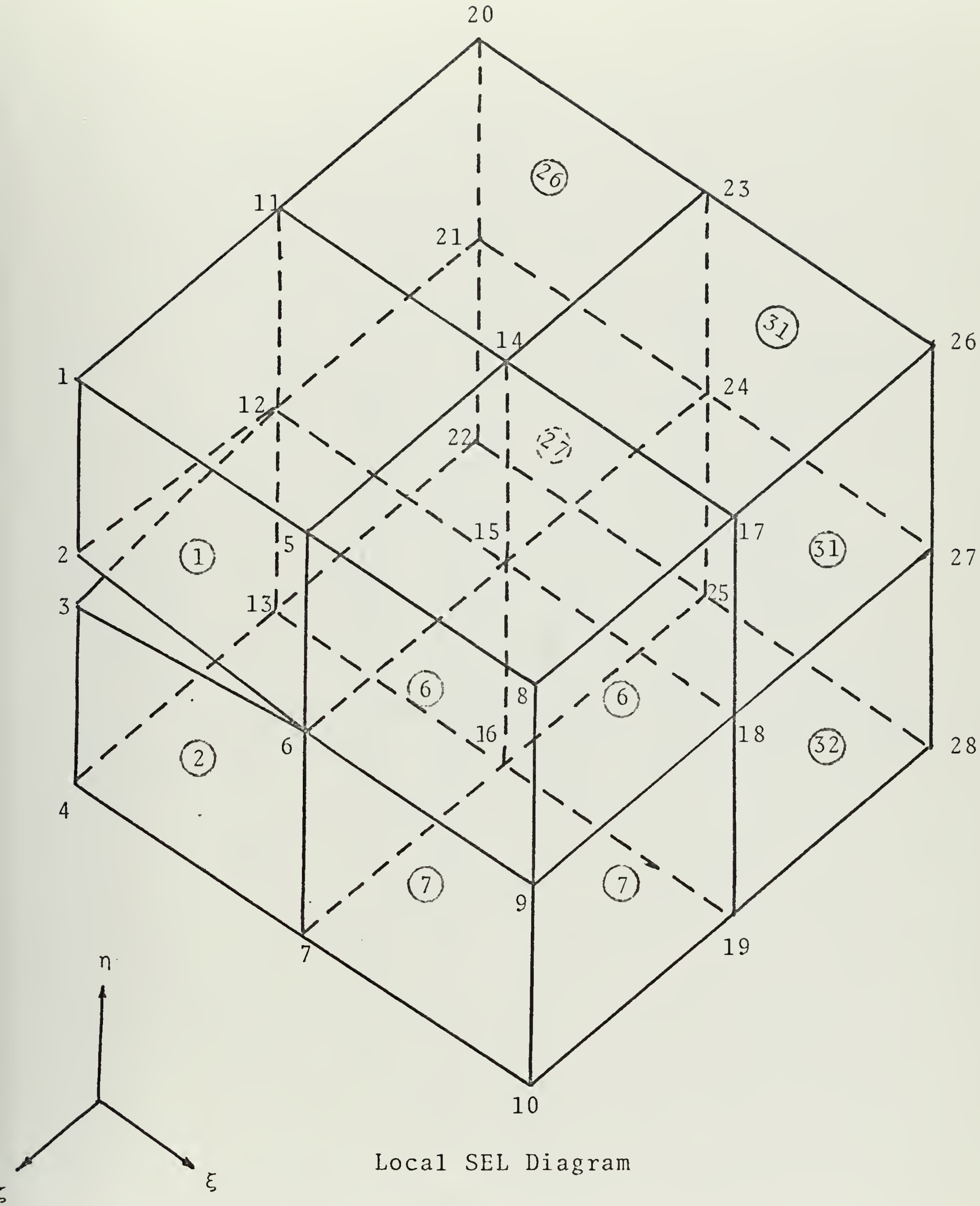
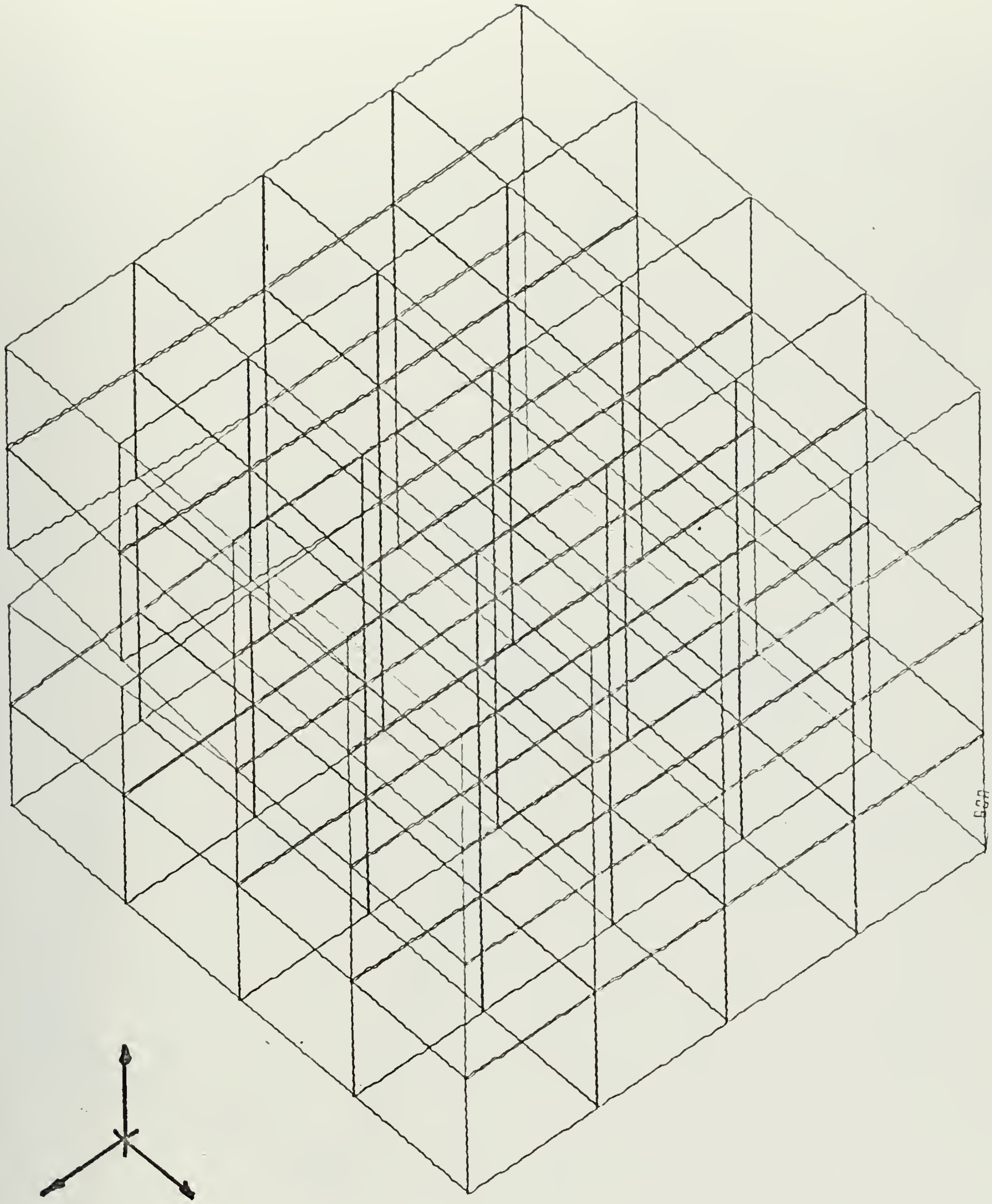
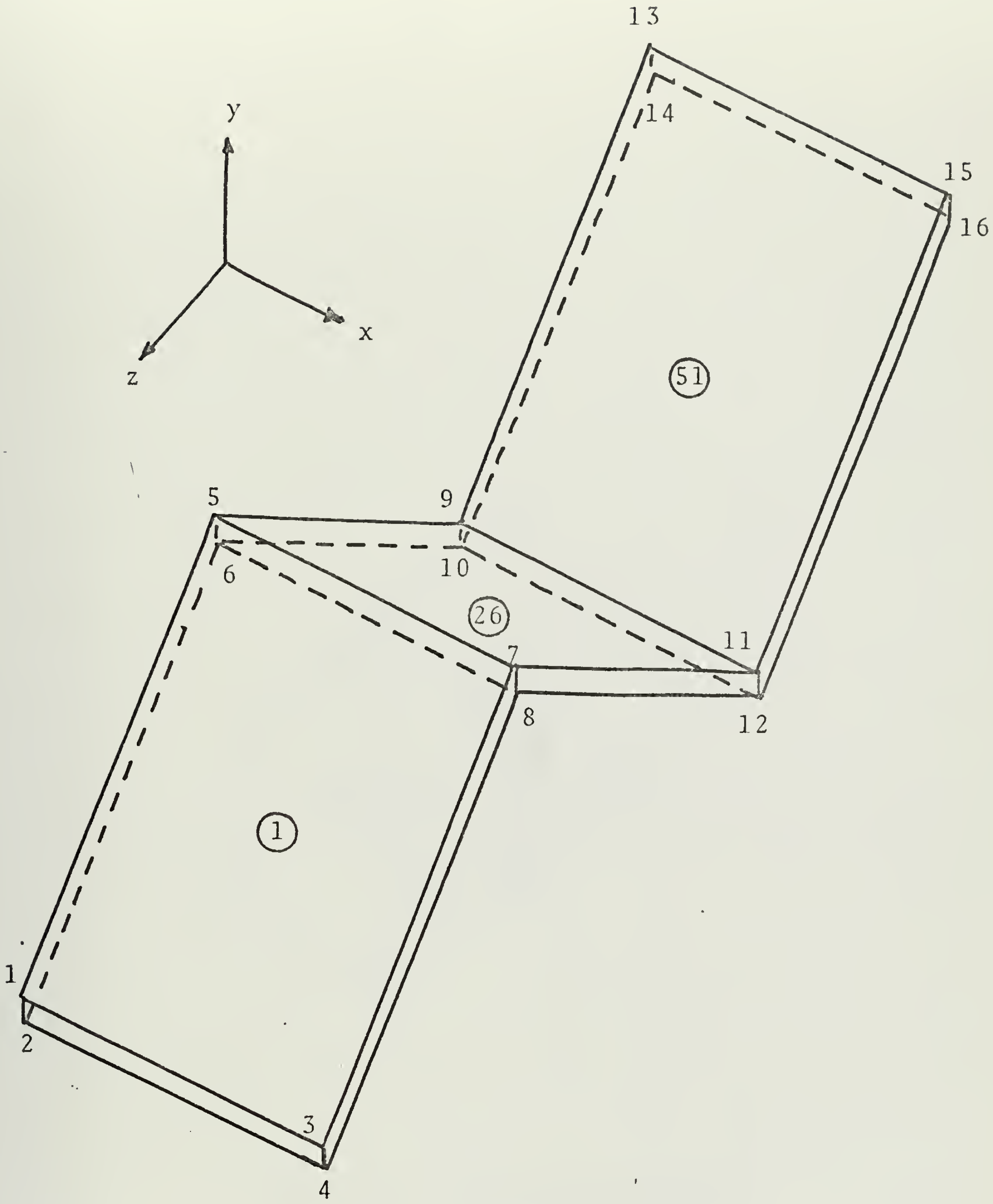


Figure 22. Crack Propagation Problem.



Final Mesh

Figure 24. Crack Propagation Problem.



Cartesian SEL Diagram

Figure 25. Folded Plate.

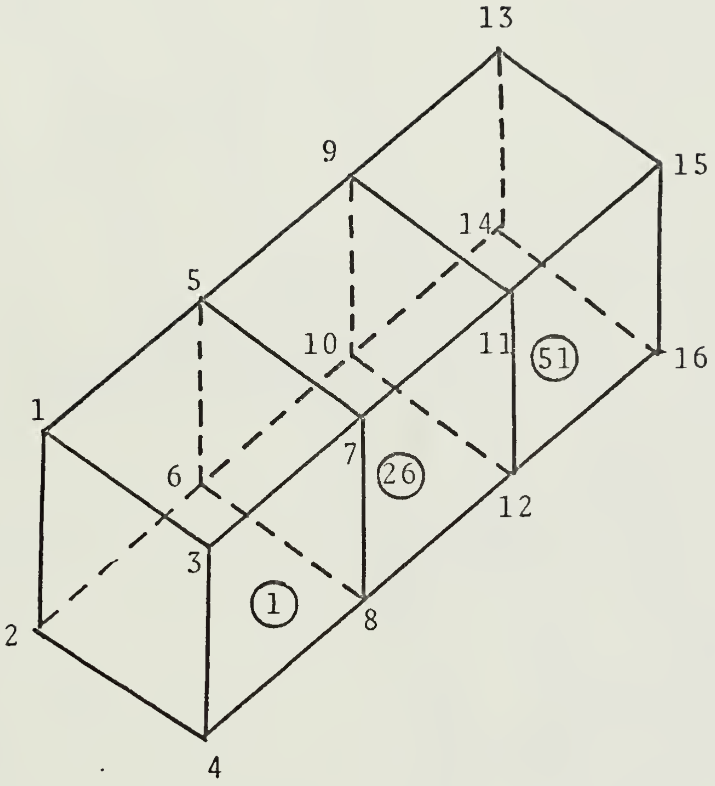
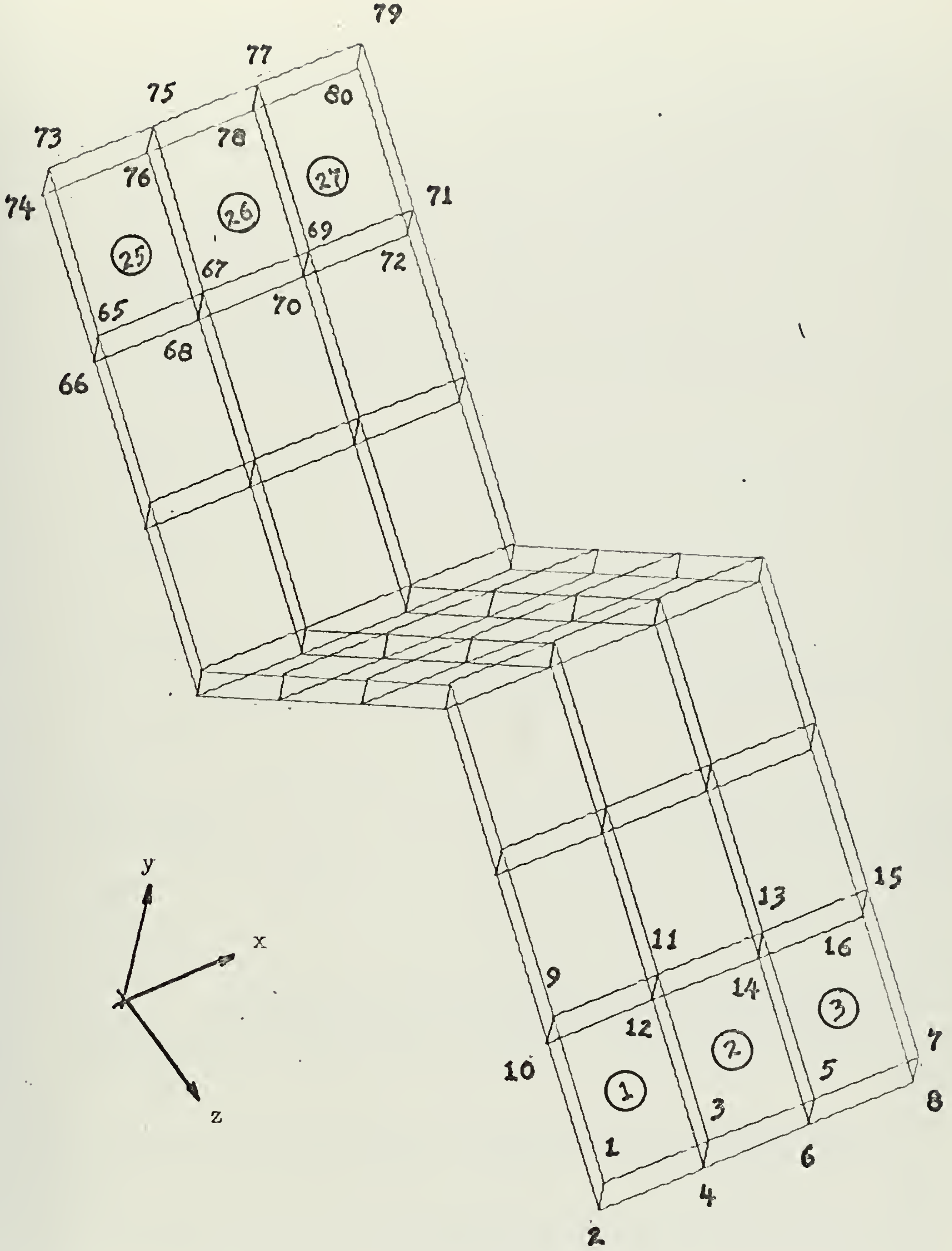


Figure 26. Local SEL Diagram.



Final Mesh

Figure 27. Folded Plate.

```
12345678901234567890123456789012345678901234567890123456789012345678901234567890

FOLDED PLATE
J.R.ADAMEK
    3         030.0  30.0  30.0
    1    1    3    3    1    2    4    3    5    6    8    7    1    8
   26    1    3    3    5    6    8    7    9   10   12   11    1    8
   51    1    3    3    9   10   12   11   13   14   16   15    1    8
    1    3     3.0                 1.2                 7.0
    1    1     1.0                 1.2                 7.0
    1    2     1.0                 1.0                 7.0
    1    4     3.0                 1.0                 7.0
    1    7     3.0                 3.2                 5.0
    1    5     1.0                 3.2                 5.0
    1    6     1.0                 3.0                 5.0
    1    8     3.0                 3.0                 5.0
   26    7     3.0                 3.2                 5.0
   26    5     1.0                 3.2                 5.0
   26    6     1.0                 3.0                 5.0
   26    8     3.0                 3.0                 5.0
   26   11     3.0                 1.2                 3.0
   26    9     1.0                 1.2                 3.0
   26   10     1.0                 1.0                 3.0
   26   12     3.0                 1.0                 3.0
   51   11     3.0                 1.2                 3.0
   51    9     1.0                 1.2                 3.0
   51   10     1.0                 1.0                 3.0
   51   12     3.0                 1.0                 3.0
   51   15     3.0                 3.2                 1.0
   51   13     1.0                 3.2                 1.0
   51   14     1.0                 3.0                 1.0
   51   16     3.0                 3.0                 1.0

12345678901234567890123456789012345678901234567890123456789012345678901234567890
```

Figure 28. TRIMEG Input Data (Example Two).

```
FOLDED PLATE
J.R.ADAMEK

MESH PARAMETERS

 NSEL  NPUNCH    NPLOT    TETA   ALPHA   BETA

   3      0        0      30.00  30.00  30.00

SUPER ELEMENT DATA

 SEL NO.        ROW   COL   SLICE  (A)   (B)   (C)   (D)   (E)   (F)   (G)   (H)  TYPE  NPTSB

   1             1     3     3      1     2     4     3     5     6     8     7     1      8
  26             1     3     3      5     6     8     7     9    10    12    11     1      8
  51             1     3     3      9    10    12    11    13    14    16    15     1      8

BOUNDARY DATA

  SEL NO. NODE NO.  NCT       X COORDINATE          Y COORDINATE          Z COORDINATE


     1         3     0     3.00000000000000      1.20000000000000      7.00000000000000
     1         1     0     1.00000000000000      1.20000000000000      7.00000000000000
     1         2     0     1.00000000000000      1.00000000000000      7.00000000000000
     1         4     0     3.00000000000000      1.00000000000000      7.00000000000000
     1         7     0     3.00000000000000      3.20000000000000      5.00000000000000
     1         5     0     1.00000000000000      3.20000000000000      5.00000000000000
     1         6     0     1.00000000000000      3.00000000000000      5.00000000000000
     1         8     0     3.00000000000000      3.00000000000000      5.00000000000000
    26         7     0     3.00000000000000      3.20000000000000      5.00000000000000
    26         5     0     1.00000000000000      3.20000000000000      5.00000000000000
    26         6     0     1.00000000000000      3.00000000000000      5.00000000000000
    26         8     0     3.00000000000000      3.00000000000000      5.00000000000000
    26        11     0     3.00000000000000      1.20000000000000      3.00000000000000
    26         9     0     1.00000000000000      1.20000000000000      3.00000000000000
    26        10     0     1.00000000000000      1.00000000000000      3.00000000000000
    26        12     0     3.00000000000000      1.00000000000000      3.00000000000000
    51        11     0     3.00000000000000      1.20000000000000      3.00000000000000
    51         9     0     1.00000000000000      1.20000000000000      3.00000000000000
    51        10     0     1.00000000000000      1.00000000000000      3.00000000000000
    51        12     0     3.00000000000000      1.00000000000000      3.00000000000000
    51        15     0     3.00000000000000      3.20000000000000      1.00000000000000
    51        13     0     1.00000000000000      3.20000000000000      1.00000000000000
    51        14     0     1.00000000000000      3.00000000000000      1.00000000000000
    51        16     0     3.00000000000000      3.00000000000000      1.00000000000000
```

Figure 29. TRIMEG Output (Input Data Check).

```
NUMBER CF ELEMENTS=  27
NUMBER CF JCINTS=  80

CCNNECTIVITY MATRIX
  EL                                                       TYPE

   1       3   1   2   4  11   9  10  12                     1
   2       5   3   4   6  13  11  12  14                     1
   3       7   5   6   8  15  13  14  16                     1
   4      11   9  10  12  19  17  18  20                     1
   5      13  11  12  14  21  19  20  22                     1
   6      15  13  14  16  23  21  22  24                     1
   7      19  17  18  20  27  25  26  28                     1
   8      21  19  20  22  29  27  28  30                     1
   9      23  21  22  24  31  29  30  32                     1
  10      27  25  26  28  35  33  34  36                     1
  11      29  27  28  30  37  35  36  38                     1
  12      31  29  30  32  39  37  38  40                     1
  13      35  33  34  36  43  41  42  44                     1
  14      37  35  36  38  45  43  44  46                     1
  15      39  37  38  40  47  45  46  48                     1
  16      43  41  42  44  51  49  50  52                     1
  17      45  43  44  46  53  51  52  54                     1
  18      47  45  46  48  55  53  54  56                     1
  19      51  49  50  52  59  57  58  60                     1
  20      53  51  52  54  61  59  60  62                     1
  21      55  53  54  56  63  61  62  64                     1
  22      59  57  58  60  67  65  66  68                     1
  23      61  59  60  62  69  67  68  70                     1
  24      63  61  62  64  71  69  70  72                     1
  25      67  65  66  68  75  73  74  76                     1
  26      69  67  68  70  77  75  76  78                     1
  27      71  69  70  72  79  77  78  80                     1

HALF BAND WIDTH FCR TRISCP STIFFNESS MATRIX=  36
```

Figure 30. TRIMEG OUTPUT

```
COCRCINATES CF JCINTS

JCINT NUMBER          X CCCRDINATE      Y COORCINATE      Z CCCRDINATE

     1                  1.0C00            1.2000            7.0000
     2                  1.CCCC            1.0CC0            7.C000
     3                  1.6667            1.2C00            7.0C00
     4                  1.6667            1.0000            7.C000
     5                  2.3333            1.2000            7.0000
     6                  2.3333            1.0000            7.0000
     7                  3.0CC0            1.2000            7.0000
     8                  3.CCCC            1.0CC0            7.CC00
     9                  1.0CC0            1.8667            6.3333
    1C                  1.CCC0            1.6667            6.3333
    11                  1.6667            1.8667            6.3333
    12                  1.6667            1.6667            6.3333
    13                  2.3333            1.8667            6.3333
    14                  2.3333            1.6667            6.3333
    15                  3.0CC0            1.8667            6.3333
    16                  3.CCCC            1.6667            6.3333
    17                  1.0CCC            2.5333            5.6667
    18                  1.CCC0            2.3333            5.6667
    19                  1.6667            2.5333            5.6667
    20                  1.6667            2.3333            5.6667
    21                  2.3333            2.5333            5.6667
    22                  2.3333            2.3333            5.6667
    23                  3.0CC0            2.5333            5.6667
    24                  3.CCC0            2.3333            5.6667
    25                  1.0000            3.2CC0            5.C000
    26                  1.0C00            3.0000            5.0000
    27                  1.6667            3.2CC0            5.0000
    28                  1.6667            3.CC00            5.0C00
    29                  2.3333            3.2000            5.0000

     ↓                    ↓                 ↓                 ↓

    72                  3.CCC0            2.3333            1.6667
    73                  1.0CC0            3.2C00            1.0000
    74                  1.0CC0            3.0000            1.0000
    75                  1.6667            3.2C00            1.0000
    76                  1.6667            3.0CC0            1.0000
    77                  2.3333            3.2000            1.0000
    78                  2.3333            3.00C0            1.0000
    79                  3.0000            3.2000            1.0000
    8C                  3.0000            3.0000            1.0000
```

Figure 30 (continued)

APPENDIX E

COMPUTER LISTING (PLIMEG)

```
C                                         **********
C                                         * PLIMEG *
C                                         **********
C
      IMPLICIT REAL*8 (A-H,O-Z)
      DIMENSICN NCT(100)
      COMMON/TITL/TITLE(12)
      CCMMON/ INT/NPT,NEL,NPUNCH,NSTOP,NJT,NPLOT,NKIND,NSEL,NGRCW,NGCOL
      CCMMON/MESH1/ NSCON(110,9),MS(110,8),MEL(110,4)
      CCMMON/CORD1/CORD(217,2)
      CCMMON/CORD2/BOUND(100,2)
      DATA MAXBJT/100/
      NGROW=10
      NGCOL=10
C
C        NGROW AND NGCOL ARE MAX NO. OF SUPER ELEMENT GRID ROWS
C        AND COLUMNS RESPECTIVELY.
C
C        MESH1 COMMON ENTRIES DIMENSIONED (I,*) WHERE I=(NGROW+1)*NGCOL.
C
C        MESH1 ALSO CONTAINED IN SUBROUTINES CCNN, COORD, AND GRIC.
C
C        CORD1 COMMON ENTRIES DIMENSIONED MAX JCINTS IN "PLISOP".
C
C        CORD1 ALSO CONTAINED IN SUBRCUTINES CCCRC AND GRIC.
C
C        CORD2 COMMON ENTRY DIMENSIONED (I,2) ANC NCT DIMENSIONED (I),
C        WHERE I=MAXBJT ABOVE. THIS IS ARBITRARY.
C
C        CORD2 ALSO CONTAINEC IN SUBRCUTINE COORC.
C
 5    READ (5,10,END=9000) (TITLE(I),I=1,6)
      READ (5,10) (TITLE(I),I=7,12)
      WRITE (6,20) (TITLE(I),I=1,6)
      WRITE (6,22) (TITLE(I),I=7,12)
      READ (5,11) NSEL,NPT,NPUNCH,NPLCT
      WRITE (6,35)
      WRITE (6,33) NSEL,NPT,NPUNCH,NPLCT
 10   FCRMAT (6A8)
 11   FCRMAT (10I5)
 20   FCRMAT ('1',6A8)
 22   FORMAT (1X,6A8)
 25   FCRMAT (3I5,2G25.17)
 26   FCRMAT (2G25.17)
 28   FCRMAT (4X,I3,6X,I3,5X,I3,2(3X,G25.15))
 29   FCRMAT (/,44X,'CENTER OF CURVATURE',/,27X,G25.15,3X,G25.15,/)
 30   FORMAT (//,' BOUNDARY DATA',//,'   SEL NC.',2X,'NODE NO.',2X,
```

```
     1'NCT',9X,'X COORDINATE',16X,'Y CCORDINATE',//)
 31   FCRMAT (10X,I3,8X,8(I3,3X),I3)
 33   FORMAT (10X,I3,3X,I3,4X,I3,5X,I3)
 34   FORMAT (///,' SUPER ELEMENT DATA',//,9X,'SEL NO.',6X,'RCW',
     13X,'COL',3X,'(A)',3X,'(B)',3X,'(C)',3X,'(D)',2X,'TYPE',2X,'NPTSB',
     22X,'CON',/)
 35   FCRMAT (///,' MESH PARAMETERS',//,10X,'NSEL',3X,'NPT',2X,'NPUNCH',
     13X,'NPLCT',/)
      NSTOP=0
      NKIND=NPT/4
      K=1
      I1=NGCOL+1
      DC 40 I=1,I1
      DO 39 J=1,NGRCW
      DC 36 L=1,9
 36   NSCCN(K,L)=0
      DO 37 M=1,8
 37   MS(K,M)=0
      DC 38 N=1,2
 38   MEL(K,N)=0
 39   K=K+1
 40   CCNTINUE
C
C        SUPER ELEMENT DATA
C
      NPTSBT=0
      WRITE (6,34)
      DC 45 N=1,NSEL
      IF (NPTSBT.GT.MAXBJT) NSTOP=2
      READ (5,11)   I,(NSCON(I,J),J=1,9)
      IF (N.EQ.NSEL) NLAST=I
      WRITE (6,31)  I,(NSCON(I,J),J=1,9)
 45   NPTSBT=NPTSBT+NSCCN(I,8)
C
C        BCUNDARY DATA
C
      WRITE (6,30)
      NSELT=NGCOL*NGROW
      I3=1
      NBS1=0
      DC 70 K=1,NSELT
      IF (NSCCN(K,2).EQ.0) GO TO 70
      I4=NSCON(K,8)+I3-1
      DC 60 I=I3,I4
      READ (5,25)   NBSEL,NBNODE,NCT(I),(BOUND(I,J),J=1,2)
      WRITE (6,28)  NBSEL,NBNODE,NCT(I),(BOUND(I,J),J=1,2)
      IF (NBSEL.LT.NBS1) NSTOP=1
      NBS1=NBSEL
```

```
      NCTI=NCT(I)
      GC TO (46,46,46),NCTI
      GC TO 47
46    PHI=.314159265358979D1*BOUND(I,2)/1.8D2
      RAD=BOUND(I,1)
      BCUND(I,1)=RAD*DCOS(PHI)
      BCUND(I,2)=RAD*DSIN(PHI)
47    GC TO (50,48,49),NCTI
      GC TO 50
48    READ (5,26) XCC,YCC
      WRITE (6,29) XCC,YCC
49    BCUND(I,1)=BOUND(I,1)+XCC
      BCUND(I,2)=BOUND(I,2)+YCC
50    II=I-1
      III=I-2
      IIII=I3-1
      IF (II.LE.0) II=1
      IF (III.LE.0) III=1
      IF ((K.EQ.NLAST).AND.(I.EQ.I4)) GO TO 51
      GC TO 52
51    II=I
      III=I-1
      IIII=I
52    IF(NCT(II).EQ.4) GC TO 53
      IF((NCT(III).EQ.5).AND.(NCT(II).EQ.5)) GO TC 55
      GC TO 6C
53    NB1=II-1
      NB2=II+1
      IF (II.EQ.IIII) NB2=II-7
      BCUND(II,1)=(BOUND(NB1,1)+BOUND(NB2,1))/2.CDO
      BCUND(II,2)=(BOUND(NB1,2)+BCUND(NB2,2))/2.ODO
      GC TO 6C
55    NB1=II-2
      NB2=II-1
      NB3=II+1
      IF (II.EQ.IIII) NB3=II-11
      BMIDX=BCUND(NB1,1)-BOUND(NB3,1)
      BMIDY=BCUND(NB1,2)-BOUND(NB3,2)
      BCUND(III,1)=BOUND(NB1,1)-BMIDX/3.ODO
      BCUND(III,2)=BOUND(NB1,2)-BMIDY/3.ODO
      BCUND(II,1)=BOUND(NB1,1)-2*BMIDX/3.ODO
      BCUND(II,2)=BOUND(NB1,2)-2*BMIDY/3.ODO
60    CCNTINUE
      I3=I4+1
70    CCNTINUE
      IF (NSTCP.EQ.1) GO TO 75
      IF (NSTCP.EQ.2) GO TO 90
      GC TO 85
```

```
75    WRITE (6,80)
80    FORMAT (///,'  DATA REJECTED***SUPER ELEMENT NUMBERS NOT IN ASCEND
     1ING ORDER FOR BOUNDARY INPUT DATA.',/,
     2'******************************************************',///)
      GO TO 5
90    WRITE (6,95) MAXBJT
95    FORMAT (///,'  DATA REJECTED***NUMBER OF BOUNDARY NODES GREATER TH
     1AN',I5,/,'********************************************************',/)
      GO TO 5
85    NSTOP=0
      CALL CONN
      IF (NSTOP.EQ.1) GO TO 5
      CALL COORD
      IF (NPLOT.NE.0) CALL GRID
      GO TO 5
9000  STOP
      END



      SUBROUTINE CONN
C
C        THIS SUBROUTINE DETERMINES ELEMENT CONNECTIVITY FOR 4,8 AND 12
C        NODAL ELEMENTS. OUTPUT IS PRINTED AND AN OPTION TO PUNCH IN
C        FORMAT COMPATIBLE WITH "PLISOP" IS INCORPORATED.
C
      IMPLICIT REAL*8 (A-H,O-Z)
      DIMENSION NLC(14,3), LCON(14)
      COMMON/INT/NPT,NEL,NPUNCH,NSTOP,NJT,NPLOT,NKIND,NSEL,NGROW,NGCOL
      COMMON/MESH1/ NSCON(110,9),MS(110,8),MEL(110,4)
      COMMON/MESH2/ NCR(10),NRR(10)
      COMMON/MESH3/ NCON(182,14)
      DATA NLC/4,1,2,3,5,6,7,8,9,10,11,12,13,14,7,8,1,2,3,4,5,6,9,10,
     111,12,13,14,10,11,12,1,2,3,4,5,6,7,8,9,13,14/
      DATA  MAXNEL/182/,MAXNJT/217/
C
C        MAX. NO. ELEMENTS (MAXNEL) AND MAX. NO. JOINTS (MAXNJT),
C        DETERMINED IN 'PLISOP'.
C
C        MESH2 COMMON ENTRY DIMENSIONED NGCOL
C
C        MESH3 COMMON ENTRY DIMENSIONED (I,14) WHERE I=MAXNEL.
C
C        MESH2 AND MESH3 ALSO CONTAINED IN SUBROUTINES COORD AND GRID.
C
20    FORMAT (///,' CONNECTIVITY MATRIX',//,' ELEMENT NUMBER ',64X,' KIN
```

```
     1C',1X,'TYPE',//)
 21   FCRMAT (//,' NUMBER OF ELEMENTS=',I4,//,' NUMBER OF JOINTS=',I4)
 25   FCRMAT (5X,I3,11X,14I5)
 26   FCRMAT (15I4)
C
C        NUMBER OF ROWS AMD CCLUMNS IN EACH GRIC CCLUMN.
C
      K=1
      DC 60 I=1,NGCCL
      NRR(I)=0
      NCR(I)=C
      DC 50 J=1,NGRCW
      NRR(I)=NRR(I)+NSCCN(K,1)
      IF (NCR(I).NE.0) GC TO 50
      IF (NSCCN(K,2).NE.C) NCR(I)=NSCCN(K,2)
 50   K=K+1
 60   CCNTINUE
      DC 80 I=1,MAXNEL
      DC 70 J=1,14
 70   NCCN(I,J)=C
 80      CONTINUE
C
C        SUPER ELEMENT CCNNECTIVITY
C
      K=1
      DC 100 I=1,NGCOL
      IF(NCR(I).EQ.0) GO TO 95
      J1=NGROW
      IF (I.EC.NGCOL) J1=NGROW-1
      DC 90 J=1,J1
      IF (NSCCN(K,1).EQ.0) GC TO 90
      L=K+1
      M=K+NGRCW
      IF (NSCCN(K,4).NE.NSCON(L,3)) GC TC 86
      MS(K,4)=1
      MS(L,1)=1
 86   IF (NSCCN(K,5).NE.NSCCN(L,6)) GC TC 87
      MS(K,5)=1
      MS(L,8)=1
 87   IF (I.EC.NGCOL) GC TO 90
      IF (NSCCN(K,6).NE.NSCON(M,3)) GC TO 88
      MS(K,7)=1
      MS(M,2)=1
 88   IF (NSCCN(K,5).NE.NSCON(M,4)) GC TC 90
      MS(K,6)=1
      MS(M,3)=1
 90   K=K+1
      GC TO 1CO
```

```
 95   K=K+NGROW
 100  CONTINUE
C
C        ELEMENT CONNECTIVITY
C
      NC1=1
      KK=1
      MM1=1
      II=0
      DO 500 I=1,NGCOL
      L1=NCR(I)
      IF (L1.EQ.0) GO TO 470
      II=II+1
      DO 450 L=1,L1
      LL1=NKIND
      LL2=NKIND+1
      IF (L.EQ.L1) LL1=LL2
      DO 430 LL=1,LL1
      L3=0
      IF ((LL.EQ.1).AND.(L.EQ.1)) L3=1
      NKIND1=NKIND
      IF ((LL.NE.1).AND.(LL.NE.LL2)) NKIND1=1
      K=KK
      M1=MM1
      DO 400 J=1,NGROW
      IF (NSCON(K,1).EQ.0) GO TO 390
      KA=K-1
      KB=NSCON(K,9)-1
      KL=K-NGROW
      KL1=KL-1
      KL2=KL+1
      KR=K+NGROW
      KR1=KR-1
      IF (LL.NE.LL2) GO TO 145
      IF (((MS(K,7).EQ.0).AND.(MS(K,8).EQ.1)).AND.(MS(KA,6).EQ.1))
     1  NC1=NC1-1
      IF (((MS(K,6).EQ.1).AND.(MS(K,7).EQ.1))
     1.AND.(KR.NE.NSCON(K,9))) GO TO 135
      GO TO 140
 135  M1=M1+NSCON(K,1)
      GO TO 390
 140  IF (MS(K,7).EQ.1) NC1=NC1-1
 145  M2=M1+NSCON(K,1)-1
      IF (M2.GT.MAXNEL) GO TO 700
      DO 350 M=M1,M2
      IF (LL.NE.1) GO TO 148
      IF (L.NE.1) GO TO 147
      IF (M.EQ.M1) MEL(K,1)=M
```

```
      IF (M.EQ.M2) MEL(K,2)=M
  147 IF (L.NE.L1) GO TC 148
      IF (M.EQ.M1) MEL(K,3)=M
      IF (M.EC.M2) MEL(K,4)=M
  148 GC TC (15C,200,25C),NKIND
C
C         LINEAR ELEMENTS
C
  15C GC TO (160,185),LL
  16C NCCN(M,1)=NC1
      NCCN(M,2)=NC1+1
      IF (L.EQ.1) GO TO 165
      NCCN(MM2,4)=NCON(M,1)
      NCCN(MM2,3)=NCON(M,2)
      MM2=MM2+1
      GC TO 3C0
  165 IF(II.EQ.1) GO TO 3C0
      IF ((MS(K,2).EQ.0).AND.(MS(K,3).EQ.0)) GC TC 300
      IF (M.NE.M1) GO TC 171
      MM3=MEL(KL,3)
      MM4=MEL(K,1)
  171 IF ((MS(K,2).EQ.1).ANC.(MS(K,3).EC.1)) GC TC 172
      GC TO 3C0
  172 IF (K.EC.NSCON(KL,9)) GC TO 300
      NCCN(MM3,4)=NCON(MM4,1)
      NCON(MM3,3)=NCON(MM4,2)
      MM3=MM3+1
      MM4=MM4+1
      GC TO 3C0
  185 NCCN(M,4)=NC1
      NCCN(M,3)=NC1+1
      GC TO 300
C
C         GUADRATIC ELEMENTS
C
  20C GC TO (205,225,245),LL
  2C5 NCCN(M,1)=NC1
      NCCN(M,2)=NC1+1
      NCCN(M,3)=NC1+2
      IF (L.EQ.1) GO TO 210
      NCCN(MM2,7)=NCON(M,1)
      NCCN(MM2,6)=NCCN(M,2)
      NCCN(MM2,5)=NCON(M,3)
      MM2=MM2+1
      GC TO 3C0
  21C IF(II.EC.1) GO TO 3C0
      IF ((MS(K,2).EQ.0).ANC.(MS(K,3).EC.0)) GO TC 300
      IF (M.NE.M1) GO TC 215
```

```
      MM3=MEL(KL,3)
      MM4=MEL(K,1)
215   IF ((MS(K,2).EQ.1).AND.(MS(K,3).EC.1)) GC TC 220
      GC TO 3CO
22C   IF (K.EQ.NSCON(KL,9)) GC TO 300
      NCCN(MM3,7)=NCON(MM4,1)
      NCCN(MM3,6)=NCON(MM4,2)
      NCCN(MM3,5)=NCON(MM4,3)
      MM3=MM3+1
      MM4=MM4+1
      GC TO 300
225   NCCN(M,8)=NC1
      NCCN(M,4)=NC1+1
      GC TO 300
245   NCCN(M,7)=NC1
      NCCN(M,6)=NC1+1
      NCCN(M,5)=NC1+2
      GC TO 3CO
C
C        CUBIC ELEMENTS
C
250   GC TO (255,285,290,295),LL
255   NCCN(M,1)=NC1
      NCCN(M,2)=NC1+1
      NCCN(M,3)=NC1+2
      NCCN(M,4)=NC1+3
      IF (L.EQ.1) GO TO 260
      NCCN(MM2,10)=NCON(M,1)
      NCCN(MM2, 9)=NCON(M,2)
      NCCN(MM2, 8)=NCON(M,3)
      NCCN(MM2, 7)=NCON(M,4)
      MM2=MM2+1
      GC TO 3CO
26C   IF(II.EC.1) GO TO 300
      IF ((MS(K,2).EQ.0).AND.(MS(K,3).EC.0)) GC TC 300
      IF (M.NE.M1) GO TO 265
      MM3=MEL(KL,3)
      MM4=MEL(K,1)
265   IF ((MS(K,2).EQ.1).AND.(MS(K,3).EC.1)) GC TC 270
      GC TO 300
27C   IF (K.EC.NSCON(KL,9)) GC TO 300
      NCCN(MM3,10)=NCON(MM4,1)
      NCCN(MM3, 9)=NCON(MM4,2)
      NCCN(MM3, 8)=NCON(MM4,3)
      NCCN(MM3, 7)=NCON(MM4,4)
      MM3=MM3+1
      MM4=MM4+1
      GC TO 300
```

```
285   NCON(M,12)=NC1
      NCON(M, 5)=NC1+1
      GO TO 300
290   NCON(M,11)=NC1
      NCON(M, 6)=NC1+1
      GO TO 300
295   NCON(M,10)=NC1
      NCON(M, 9)=NC1+1
      NCON(M, 8)=NC1+2
      NCON(M, 7)=NC1+3
300   NC1=NC1+NKIND1
      NCON(M,13)=NKIND
      NCON(M,14)=NSCON(K,7)
350   CONTINUE
      IF ((II.NE.1).AND.(L3.EQ.1)) GO TO 355
      GO TO 375
355   IF ((MS(K,2).EQ.0).AND.(MS(K,3).EQ.0)) GO TO 375
      MM5=MEL(K,2)
      MM6=MEL(KL,4)
      MM7=MEL(KL1,4)
      MM8=MEL(KL2,3)
      MM9=MEL(KL,3)
      MM10=MEL(K,1)
      GO TO (360,365,370),NKIND
360   IF (MS(K,2).NE.1) GO TO 362
      NCON(MM9,4)=NCON(MM10,1)
      IF (MS(KL,8).EQ.1) NCON(MM7,3)=NCON(MM9,4)
362   IF (MS(K,3).NE.1) GO TO 375
      NCON(MM6,3)=NCON(MM5,2)
      IF (MS(KL,5).EQ.1) NCON(MM8,4)=NCON(MM6,3)
      GO TO 375
365   IF (MS(K,2).NE.1) GO TO 367
      NCON(MM9,7)=NCON(MM10,1)
      IF (MS(KL,8).EQ.1) NCON(MM7,5)=NCON(MM9,7)
367   IF (MS(K,3).NE.1) GO TO 375
      NCON(MM6,5)=NCON(MM5,3)
      IF (MS(KL,5).EQ.1) NCON(MM8,7)=NCON(MM6,5)
      GO TO 375
370   IF (MS(K,2).NE.1) GO TO 372
      NCON(MM9,10)=NCON(MM10,1)
      IF (MS(KL,8).EQ.1) NCON(MM7,7)=NCON(MM9,10)
372   IF (MS(K,3).NE.1) GO TO 375
      NCON(MM6,7)=NCON(MM5,4)
      IF (MS(KL,5).EQ.1) NCON(MM8,10)=NCON(MM6,7)
375   IF ((MS(K,4).EQ.0).AND.(L3.EQ.1)) NC1=NC1+1
      IF ((((MS(K,4).EQ.0).OR.(MS(K,5).EQ.0)).AND.(L3.EQ.0))
     1.AND.(LL.NE.LL2)) NC1=NC1+1
      IF(((L3.NE.1).AND.(LL.NE.LL2)).AND.(K.EQ.KB)) NC1=NC1+1
```

```
      IF (((MS(K,5).EQ.0).AND.(MS(K,6).NE.1)).AND.(LL.EQ.LL2)) NC1=NC1+1
380   M1=M2+1
390   K=K+1
400   CONTINUE
430   CONTINUE
      MM2=MM1
      MM1=M1
450   CONTINUE
      KK=K
      GO TO 500
470   KK=KK+NGROW
500   CONTINUE
      NEL=M
      IF (NKIND.EQ.1) NJT=NCON(NEL,3)
      IF (NKIND.EQ.2) NJT=NCON(NEL,5)
      IF (NKIND.EQ.3) NJT=NCON(NEL,7)
      WRITE (6,21) NEL,NJT
      IF (NJT.GT.MAXNJT) GO TO 800
      WRITE (6,20)
      NBAND=0
      DO 600 I=1,NEL
      NB1=NCON(I, 1)
      GO TO (550,560,570),NKIND
550   NB2=NCON(I, 3)
      NB3=NCON(I, 4)
      GO TO 580
560   NB2=NCON(I, 5)
      NB3=NCON(I, 7)
      GO TO 580
570   NB2=NCON(I, 7)
      NB3=NCON(I,10)
580   NBAND=MAX0(NBAND,(NB2-NB1))
      NBAND=MAX0(NBAND,(NB3-NB1))
      DO 590 J=1,14
      K=NLC(J,NKIND)
590   LCON(J)=NCON(I,K)
      IF(NPUNCH.EQ.0) GO TO 600
      WRITE (7,26) I,(LCON(J),J=1,14)
600   WRITE (6,25) I,(LCON(J),J=1,14)
      NBAND=(NBAND+1)*2
      WRITE (6,650) NBAND
650   FORMAT (///,' HALF BAND WIDTH FOR PLISOP STIFFNESS MATRIX=',I5)
      RETURN
700   NSTOP=1
      WRITE (6,725) MAXNEL
725   FORMAT (///,' DATA REJECTED***NUMBER OF ELEMENTS GREATER THAN',I5
     1,/,' ********************************************************')
      RETURN
```

```
 80C  NSTOP=1
      WRITE (6,825) MAXNJT
 825  FCRMAT (///,' DATA REJECTED***NUMBER OF JCINTS GREATER THAN',I5
     1,/,' ************************************************************')
      RETURN
      END


      SUBROUTINE COORD
C
C        THIS SUBROUTINE DETERMINES X,Y COORDINATES CF JCINTS FOR 4, 8,
C        AND 12 NODAL ELEMENTS. OUTPUT IS PRINTED AND AN CPTICN TO FUNCH
C        IN FCRMAT COMPATIBLE WITH 'PLISCP' IS INCCRPORATED
C
      IMPLICIT REAL*8 (A-H,O-Z)
      DIMENSICN XI(12),ETA(12)
      DIMENSICN NQ1(3),NC1(4)
      CCMMON/INT/NPT,NEL,NPUNCH,NSTOP,NJT,NPLOT,NKIND,NSEL,NGRCW,NGCOL
      CCMMON/MESH1/ NSCCN(110,9),MS(11C,8),MEL(11C,4)
      CCMMON/MESH2/ NCR(1C),NRR(10)
      CCMMON/MESH3/ NCCN(182,14)
      CCMMCN/CCRD1/CORD(217,2)
      CCMMCN/CORC2/BOUND(100,2)
      CCMMON/SF/VAL(12)
      DATA NQ1/1,8,7/
      CATA NC1/1,10,11,12/
 1C   FCRMAT (///,' COORDINATES CF JCINTS',//,' JCINT NUMBER',8X,'X COOR
     1DINATE',5X,'Y COORDINATE',//)
 20   FCRMAT (5X,I3,12X,G14.5,3X,G14.5)
 25   FCRMAT (I1C,2G15.8)
      II=1
      K=1
C
C        GRID COLUMN LOOP
C
      CC 800 I=1,NGCOL
      L1=NCR(I)
      IF (L1.EG.0) GO TO 790
C
C        GRID RCW LOOP
C
      CC 700 J=1,NGROW
      IF (NSCCN(K,1).EQ.0) GO TO 690
      M1=MEL(K,1)
      NPTB=NSCCN(K,8)
      DELXI=2.0D0/(NKIND*NSCCN(K,2))
      CELETA=2.0C0/(NKINC*NSCCN(K,1))
      XIVAL=-1.0D0
```

```
C
C           SUPER ELEMENT COLUMN LOOP
C
      DO 600 L=1,L1
      ETAVAL=1.0D0
      M2=M1+NSCON(K,1)-1
C
C           SUPER ELEMENT ROW LOOP
C
      DO 500 M=M1,M2
      GO TO (100,150,250),NKIND
C
C           LINEAR ELEMENTS
C
 100  DO 110 N=1,2
 110  XI(N)=XIVAL
      DO 120 N=3,4
 120  XI(N)=XIVAL+  DELXI
      DO 130 N=1,4,3
 130  ETA(N)=ETAVAL
      DO 140 N=2,3
 140  ETA(N)=ETAVAL-DELETA
      GO TO 350
C
C           QUADRATIC ELEMENTS
C
 150  DO 160 N=1,3
 160  XI(N)=XIVAL
      DO 170 N=4,8,4
 170  XI(N)=XIVAL+  DELXI
      DO 180 N=5,7
 180  XI(N)=XIVAL+2*DELXI
      DO 200 N=1,3
      N1=NQ1(N)
 200  ETA(N1)=ETAVAL
      DO 210 N=2,6,4
 210  ETA(N)=ETAVAL-  DELETA
      DO 220 N=3,5
 220  ETA(N)=ETAVAL-2*DELETA
      GO TO 350
C
C           CUBIC ELEMENTS
C
 250  DO 260 N=1,4
 260  XI(N)=XIVAL
      DO 270 N=5,12,7
 270  XI(N)=XIVAL+  DELXI
      DO 280 N=6,11,5
```

```
28C   XI(N)=XIVAL+2*DELXI
      CC 290 N=7,10
29C   XI(N)=XIVAL+3*DELXI
      CC 300 N=1,4
      N1=NC1(N)
3CC   ETA(N1)=ETAVAL
      CC 310 N=2,9,7
31C   ETA(N)=ETAVAL-  CELETA
      DC 320 N=3,8,5
32C   ETA(N)=ETAVAL-2*DELETA
      CC 330 N=4,7
33C   ETA(N)=ETAVAL-3*DELETA
35C   CC 400 N=1,NPT
      N1=NCON(M,N)
      XI1=XI(N)
      ETA1=ETA(N)
      CALL SHAPE (XI1,ETA1,NPTB)
      CCRD(N1,1)=0.DO
      CCRD(N1,2)=0.DO
      III=II
      CC 360 NN=1,NPTB
      CCRD(N1,1)=CORD(N1,1)+VAL(NN)*BCUND(III,1)
      CCRD(N1,2)=CORD(N1,2)+VAL(NN)*BCUND(III,2)
36C   III=III+1
40C   CCNTINUE
      ETAVAL=ETAVAL-NKIND*DELETA
500   CCNTINUE
      M1=M2+NRR(I)-NSCCN(K,1)+1
      XIVAL=XIVAL+NKIND*DELXI
60C   CCNTINUE
      II=II+NPTB
69C   K=K+1
70C   CCNTINUE
      GC TO 8C0
79C   K=K+NGRCW
80C   CCNTINUE
      WRITE (6,1C)
      CC 850 I=1,NJT
      IF (NPUNCH.EQ.0) GC TC 850
      WRITE (7,25) I,(CORD(I,J),J=1,2)
85C   WRITE (6,20) I,(CORD(I,J),J=1,2)
      RETURN
      END
```

```
      SUBROUTINE SHAPE(X,Y,NPEL)
      IMPLICIT REAL*8(A-H,O-Z)
      DIMENSION XYL(4,2),XYQ(8,2),XYC(12,2),IPERM(4)
      COMMON/SF/VAL(12)
      DATA XYL/1.0D0,-1.0D0,-1.0D0,1.0D0,1.0D0,1.0D0,-1.0D0,-1.0D0/
      DATA XYQ/1.0D0,0.0D0,-1.0D0,-1.0D0,-1.0D0,0.0D0,1.0D0,1.0D0,1.0D0,
     11.0D0,1.0D0,0.0D0,-1.0D0,-1.0D0,-1.0D0,0.0D0/
      DATA XYC/1.0D0,.333333333333333D0,-.333333333333333D0,-1.0D0,-1.0D
     10,-1.0D0,-1.0D0,-.333333333333333D0,.333333333333333D0,1.0D0,1.0D0
     2,1.0D0,1.0D0,1.0D0,1.0D0,1.0D0,.333333333333333D0,-.3333333333333
     333D0,-1.0D0,-1.0D0,-1.0D0,-1.0D0,-.333333333333333D0,.333333333333
     433D0/
      FL(X,Y,X1,Y1)=(ONE+X*X1)*(ONE+Y*Y1)/FOUR
      FQC(X,Y,X1,Y1)=(ONE+X*X1)*(ONE+Y*Y1)*(X*X1+Y*Y1-ONE)/FOUR
      FQM(X,Y,Y1)=(ONE-X*X)*(ONE+Y*Y1)/TWO
      FCC(X,Y,X1,Y1)=(ONE+X*X1)*(ONE+Y*Y1)*(.9D1*(X*X+Y*Y)-.1D2)/3.2D1
      FCM(X,Y,X1,Y1)=(ONE-X*X)*(ONE+.9D1*X*X1)*(ONE+Y*Y1)*.9D1/3.2D1
      ONE=1.0D0
      TWO=2.0D0
      FOUR=4.0D0
      IGO=NPEL/4
      GO TO (50,150,450),IGO
 50   CONTINUE
C        LINEAR FUNCTIONS
      DO 100 I=1,4
      X1=XYL(I,1)
      Y1=XYL(I,2)
 100  VAL(I)=FL(X,Y,X1,Y1)
      RETURN
 150  CONTINUE
C        QUADRATIC FUNCTIONS
      DO 200 I=1,7,2
      X1=XYQ(I,1)
      Y1=XYQ(I,2)
 200  VAL(I)=FQC(X,Y,X1,Y1)
      DO 300 I=2,6,4
      Y1=XYQ(I,2)
 300  VAL(I)=FQM(X,Y,Y1)
      DO 400 I=4,8,4
      X1=XYQ(I,1)
 400  VAL(I)=FQM(Y,X,X1)
      RETURN
 450  CONTINUE
C        CUBIC FUNCTIONS
      DO 500 I=1,10,3
      X1=XYC(I,1)
      Y1=XYC(I,2)
 500  VAL(I)=FCC(X,Y,X1,Y1)
```

```
      IPERM(1)=2
      IPERM(2)=3
      IPERM(3)=8
      IPERM(4)=9
      DO 600 I=1,4
      IJ=IPERM(I)
      X1=XYC(IJ,1)
      Y1=XYC(IJ,2)
  600 VAL(IJ)=FCM(X,Y,X1,Y1)
      IPERM(1)=5
      IPERM(2)=6
      IPERM(3)=11
      IPERM(4)=12
      DO 700 I=1,4
      IJ=IPERM(I)
      X1=XYC(IJ,1)
      Y1=XYC(IJ,2)
  700 VAL(IJ)=FCM(Y,X,Y1,X1)
      RETURN
      END



      SUBROUTINE GRID
      IMPLICIT REAL*8 (A-H,O-Z)
      REAL*4 X,Y,RANGE,XSCALE,YSCALE
      REAL LABEL/4H    /
      DIMENSION X(217), Y(217), RANGE(4)
      COMMON/TITL/TITLE(12)
      COMMON/INT/NPT,NEL,NPUNCH,NSTOP,NJT,NPLOT,NKIND,NSEL,NGROW,NGCOL
      COMMON/MESH1/ NSCON(110,9),MS(110,8),MEL(110,4)
      COMMON/MESH2/ NCR(10),NRR(10)
      COMMON/MESH3/ NCON(182,14)
      COMMON/CORD1/CORD(217,2)
C
C        X,Y DIMENSIONED MAXNJT
C
      DATA ITYPE/0/ ,IXUP/15/,IYRT/0/ ,MDXAX/2/ ,MDYAX/2/ ,IWIDE/9/ ,
     1IHIGH/15/ ,IGRID/0/
      XMAX=-1.0D+20
      YMAX=-1.0D+20
      XMIN= 1.0D+20
      YMIN= 1.0D+20
      DO 20 I=1,NJT
      XMAX=DMAX1(XMAX,CORD(I,1))
      YMAX=DMAX1(YMAX,CORD(I,2))
      XMIN=DMIN1(XMIN,CORD(I,1))
```

```
 20    YMIN=DMIN1(YMIN,CCRD(I,2))
       IF (XMIN.GE.0.DO) GO TO 40
       XMAX=XMAX-XMIN
       CC 30 I=1,NJT
 30    CCRD(I,1)=CORD(I,1)-XMIN
 40    IF (YMIN.GE.0.DO) GC TO 60
       YMAX=YMAX-YMIN
       CC 50 I=1,NJT
 50    CCRD(I,2)=CCRD(I,2)-YMIN
 60    GC TO (70,110),NPLOT
C         PLOT CN PRINTER
 70    RANGE(1)=XMAX
       RANGE(2)=0.0
       RANGE(3)=YMAX
       RANGE(4)=0.0
       IF (RANGE(1).LT.RANGE(3)) RANGE(1)=RANGE(3)
       IF (RANGE(1).GT.RANGE(3)) RANGE(3)=RANGE(1)
       CC 80 I=1,NJT
       X(I)=CCRD(I,1)
 80    Y(I)=CORD(I,2)
       WRITE (6,90)
 90    FCRMAT ('1')
       CALL UTPLOT (X,Y,NJT,RANGE,1,0)
       RETURN
C         PLOT CN PLOTTER
 110   XSCALE=1.5DO*(YMAX/9.DO)
       YSCALE=1.5DO*(XMAX/15.DO)
       IF (XSCALE.GT.YSCALE) YSCALE=XSCALE
       IF (XSCALE.LT.YSCALE) XSCALE=YSCALE
       N1=NPT+1
       MC=1
       CC 150 I=1,NEL
       IF (I.EC.NEL) MC=3
       CC 120 J=1,NPT
       J1=NCON(I,J)
       IF (J.EC.1) J2=J1
       X(J)=CCRD(J1,2)
 120   Y(J)=-CCRD(J1,1)
       J=J+1
       X(J)=CCRD(J2,2)
       Y(J)=-CCRD(J2,1)
       CALL DRAW (N1,X ,Y ,MC,ITYPE,LABEL,TITLE,XSCALE,YSCALE,IXUP,IYRT,
      1MCXAX,MCYAX,IWIDE,IHIGH,IGRID,LAST)
       MC=2
 150   CCNTINUE
 200   CCNTINUE
       RETURN
       END
```

APPENDIX F

COMPUTER LISTING (TRIMEG-1)

```
C                                   ************
C                                   * TRIMEG-1 *
C                                   ************
C
      IMPLICIT REAL*8 (A-H,O-Z)
      IMPLICIT INTEGER*2 (I-N)
      DIMENSICN NCT(200)
      CCMMON/TITL/TITLE(12)
      CCMMON/INT/NPT,NEL,NPUNCH,NSTOP,NJT,NPLOT,NKIND,NSEL,NGROW,NGCOL,
     1NGSLCE
      CCMMON/MESH1/ NSCON(125,13), MF(125,8), ME(125,8), MFB(125,4),
     1MEA(125,4),  MEL(125,4),  NELB(125),  NELP(125)
      CCMMCN/CORD1/CORD(1296,3)
      CCMMCN/CCRD2/BOUND(200,3)
      DATA MAXBJT/200/
      NGROW=5
      NGCCL=5
      NGSLCE=5
C
C       NGROW, NGCOL AND NGSLCE ARE MAX NO. OF SUPER ELEMENT ROWS,
C       COLUMNS AND SLICES RESPECTIVELY.
C
C       MESH1 COMMON ENTRIES DIMENSIONED (I,*),
C       WHERE I=(NGROW+1)*NGCOL*(NGSLCE+1)
C
C       MESH1 ALSO CONTAINEC IN SUBROUTINES CONN, COORD, AND GRID.
C
C       CORD1 COMMON ENTRIES DIMENSIONED MAX JCINTS IN "TRISOP".
C
C       CORD1 ALSO CONTAINED IN SUBROUTINES CCCRC AND GRIC.
C
C       CCRD2 COMMON ENTRY DIMENSIONED (I,3) AND NCT DIMENSIONED (I),
C       WHERE I=MAXBJT ABOVE. THIS IS ARBITRARY.
C
C       CORD2 ALSO CONTAINED IN SUBRCUTINE CCCRD.
C
 5    READ (5,10,END=900C) (TITLE(I),I=1,6)
      READ (5,10) (TITLE(I),I=7,12)
      WRITE (6,20) (TITLE(I),I=1,6)
      WRITE (6,22) (TITLE(I),I=7,12)
      READ (5, 9) NSEL,NPUNCH,NPLOT,TETA,ALPHA,BETA
      WRITE (6,35)
      WRITE (6,33) NSEL,NPUNCH,NPLOT,TETA,ALPHA,BETA
 9    FCRMAT (3I5,3F5.0)
 10   FCRMAT (6A8)
 11   FCRMAT (14I5)
 20   FCRMAT ('1',6A8)
 22   FCRMAT (1X,6A8)
```

```
   25 FCRMAT (3I5,3F20.0)
   28 FCRMAT (4X,I3,6X,I3,5X,I3,3(3X,G25.15))
   30 FORMAT (//,' BOUNDARY DATA',//,'    SEL NC.',2X,'NODE NO.',2X,
     1'NCT',9X,'X COORDINATE',16X,'Y CCORDINATE',16X,'Z CCCRDINATE',//)
   31 FCRMAT (10X,I3,8X,12(I3,3X),I3)
   33 FCRMAT (10X,I3,3X,I3,6X,I3,4X,3F7.2)
   34 FCRMAT (///,' SUPER ELEMENT DATA',//,9X,'SEL NO.',6X,'ROW',
     1'   COL  SLICE  (A)    (B)    (C)    (D)    (E)    (F)    (G)    (H)  TYP
     2E  NPTSB',/)
   35 FCRMAT (///,' MESH PARAMETERS',//,10X,'NSEL  NPUNCH   NPLOT',4X,
     1  'TETA',3X,'ALPHA',3X,'BETA',/)
      PI=3.141592654D0
      TETA=TETA*PI/180.0D0
      ALPHA=ALPHA*PI/18C.0D0
      BETA=BETA*PI/180.0D0
      NSTOP=0
      K=1
      DC 40 MM=1,NGSLCE
      DC 40 I=1,NGCCL
      DC 39 J=1,NGROW
      DC 36 L=1,13
   36 NSCCN(K,L)=0
      DC 37 M=1,8
      MF(K,M)=0
      MB(K,M)=0
   37 MEL(K,M)=0
      DC 38 N=1,4
      MFB(K,N)=0
   38 MBA(K,N)=0
   39 K=K+1
   40 CCNTINUE
C        SUPER ELEMENT DATA
      NPTSBT=C
      WRITE (6,34)
      DC 60 N=1,NSEL
      IF (NPTSBT.GT.MAXBJT) NSTOP=2
      READ (5,11)   I,(NSCON(I,J),J=1,13)
      WRITE (6,31)  I,(NSCON(I,J),J=1,13)
   60 NPTSBT=NPTSBT+NSCCN(I,13)
C        BCUNDARY DATA
      WRITE (6,30)
      NLIN=0
      NBS1=0
      DC 70 I=1,NPTSBT
      READ (5,25)   NBSEL,NBNODE,NCT(I),(BCUND(I,J),J=1,3)
      IF (NBSEL.LT.NBS1) NSTOP=1
      NBS1=NBSEL
      IF (NCT(I).GT.0) NLIN=1
```

```
 70   WRITE (6,28)  NBSEL,NBNODE,NCT(I),(BOUND(I,J),J=1,3)
      IF (NSTCP.EQ.1) GO TO 170
      IF (NSTCP.EQ.2) GO TO 180
C        STRAIGHT BOUNDARY MID-SIDE NODES
      IF (NLIN.EQ.0) GO TO 190
      K=1
      NSELT=NGCOL*NGROW*NGSLCE
      DO 160 J=1,NSELT
      IF (NSCON(J,1).EQ.0) GO TO 160
      IF (NSCON(J,13).EQ.  8) GO TO 155
      NPT1=NSCON(J,13)
      DO 150 I=1,NPT1
      IF (NSCON(J,13).EQ.32) GO TO 120
      IF (NCT(K).NE.1) GO TO 150
      IF ((I.GE.9).AND.(I.LE.12)) GO TO 100
      M=K-1
      N=K+1
      IF ((I.EQ.8).OR.(I.EQ.20)) N=K-7
      GO TO 110
 100  I1=I-8
      GO TO (102,104,106,108),I1
 102  M=K-8
      N=K+4
      GO TO 110
 104  M=K-7
      N=K+5
      GO TO 110
 106  M=K-6
      N=K+6
      GO TO 110
 108  M=K-5
      N=K+7
 110  BOUND(K,1)=(BOUND(M,1)+BOUND(N,1))/2.0D0
      BOUND(K,2)=(BOUND(M,2)+BOUND(N,2))/2.0D0
      BOUND(K,3)=(BOUND(M,3)+BOUND(N,3))/2.0D0
      GO TO 150
 120  IF (NCT(K).NE.2) GO TO 150
      IF ((I.GE.13).AND.(I.LE.20)) GO TO 130
      K1=K+1
      I1=I+1
      IF ((NCT(K1).NE. 2).OR.(I1.EQ.13)) GO TO 150
      M=K-1
      N=K+2
      IF ((I.EQ.11).OR.(I.EQ.31)) N=K-10
       GO TO 144
 130  K1=K+4
      I1=I+4
      IF (I1.GT.20) GO TO 150
```

```
      I2=I-12
      GO TO (137,139,141,143),I2
137   M=K-12
      N=K+8
      GO TO 144
139   M=K-10
      N=K+10
      GO TO 144
141   M=K-8
      N=K+12
      GO TO 144
143   M=K-6
      N=K+14
144   BMIDX=BOUND(M,1)-BOUND(N,1)
      BMIDY=BOUND(M,2)-BOUND(N,2)
      BMIDZ=BOUND(M,3)-BOUND(N,3)
      BOUND(K,1)=BOUND(M,1)-BMIDX/3.0D0
      BOUND(K,2)=BOUND(M,2)-BMIDY/3.0D0
      BOUND(K,3)=BOUND(M,3)-BMIDZ/3.0D0
      BOUND(K1,1)=BOUND(M,1)-2*BMIDX/3.0D0
      BOUND(K1,2)=BOUND(M,2)-2*BMIDY/3.0D0
      BOUND(K1,3)=BOUND(M,3)-2*BMIDZ/3.0D0
150   K=K+1
      GO TO 160
155   K=K+8
160   CONTINUE
      GO TO 190
170   WRITE (6,175)
175   FORMAT (///,'  DATA REJECTED***SUPER ELEMENT NUMBERS NOT IN ASCEND
     1ING ORDER FOR BOUNDARY INPUT DATA.',/,
     2'****************************************************',///)
      GO TO 5
180   WRITE (6,185) MAXBJT
185   FORMAT (///,'  DATA REJECTED***NUMBER OF BOUNDARY NODES GREATER TH
     1AN',I5,/,'**************************************************',/)
      GO TO 5
190   NSTOP=0
      CALL CONN
      IF (NSTOP.EQ.1) GO TO 5
      CALL COORD
      IF (NPLOT.NE.1) GO TO 5
      CALL TRFR(TETA,ALPHA,BETA)
      CALL GRID
      GO TO 5
9000  STOP
      END
```

```
      SUBROUTINE CONN
C
C        THIS SUBROUTINE DETERMINES ELEMENT CONNECTIVITY. OUTPUT IS
C        PRINTED WITH OPTION TO PUNCH IN FORMAT COMPATIBLE WITH "TRISOP"
C
      IMPLICIT REAL*8 (A-H,O-Z)
      IMPLICIT INTEGER*2 (I-N)
      DIMENSION MS(8),NC(4),MBK(4,4)
      COMMON/INT/NPT,NEL,NPUNCH,NSTOP,NJT,NPLOT,NKIND,NSEL,NGROW,NGCOL,
     1NGSLCE
      COMMON/MESH1/ NSCON(125,13), MF(125,8), MB(125,8), MFB(125,4),
     1MBA(125,4),  MEL(125,4),  NELB(125),  NELP(125)
      COMMON/MESH2/ NRR(5,5),NCR(5,5),NSR(5),NELGS(5)
      COMMON/MESH3/ NCON(200,9)
      DATA  MAXNEL/200/,MAXNJT/1296/
C
C        MAX. NO. ELEMENTS (MAXNEL) AND MAX. NO. JOINTS (MAXNJT),
C        DETERMINED IN 'TRISOP'.
C
C        MESH2 COMMON ENTRY DIMENSIONED (NGSLCE,NGCOL) OR (NGSLCE).
C
C        MESH3 COMMON ENTRY DIMENSIONED (I,9), WHERE I=MAXNEL.
C
C        MESH2 AND MESH3 ALSO CONTAINED IN SUBROUTINES COORD AND GRID.
C
 10   FORMAT (///,' CONNECTIVITY MATRIX',//,4X,'EL',50X,'TYPE',//)
 11   FORMAT (9I5)
 12   FORMAT (I6,4X, 8I5,4X,I4)
 13   FORMAT (//,' NUMBER OF ELEMENTS=',I4,//,' NUMBER OF JOINTS=',I4)
C
C        ZERO CONNECTIVITY MATRIX
C
      DO 30 I=1,MAXNEL
      DO 25 J=1,9
 25   NCON(I,J)=0
 30      CONTINUE
C
C        NUMBER OF ROWS AND COLUMNS IN EACH GRID COLUMN
C               AND SUPER ELEMENT CONNECTIVITY
C
      K=1
      L1=NGROW-1
      DO 110 I=1,NGSLCE
```

```
      NSR(I)=0
      DC 110 J=1,NGCOL
      NRR(I,J)=0
      NCR(I,J)=0
      DC 100 L=1,NGROW
      IF (((I.EQ.NGSLCE).AND.(J.EQ.NGCOL)).AND.(L.EQ.L1)) GO TO 100
      IF (NSCCN(K,1).EQ.0) GC TO 100
      NRR(I,J)=NRR(I,J)+NSCON(K,1)
      NCR(I,J)=NSCON(K,2)
      NSR(I)=NSCCN(K,3)
      K1=K+1
      K2=K+NGRCW
      K3=K+NGRCW*NGCOL
      IF (NSCCN(K, 5).NE.NSCON(K1, 4)) GO TO 35
      MF(K ,4)=1
      MF(K1,1)=1
35    IF (NSCCN(K, 6).NE.NSCON(K1, 7)) GO TO 40
      MF(K ,5)=1
      MF(K1,8)=1
40    IF (J.EQ.NGCOL) GO TO 50
      IF (NSCCN(K, 6).NE.NSCON(K2, 5)) GO TO 45
      MF(K ,6)=1
      MF(K2,3)=1
45    IF (NSCCN(K, 7).NE.NSCCN(K2, 4)) GO TO 50
      MF(K ,7)=1
      MF(K2,2)=1
50    IF (NSCON(K, 9).NE.NSCCN(K1, 8)) GC TO 55
      MB(K ,4)=1
      MB(K1,1)=1
55    IF (NSCCN(K,10).NE.NSCON(K1,11)) GO TO 60
      MB(K ,5)=1
      MB(K1,8)=1
60    IF (J.EQ.NGCOL) GO TO 70
      IF (NSCON(K,10).NE.NSCON(K2, 9)) GC TO 65
      MB(K ,6)=1
      MB(K2,3)=1
65    IF (NSCCN(K,11).NE.NSCON(K2, 8)) GO TO 70
      MB(K ,7)=1
      MB(K2,2)=1
70    IF (I.EQ.NGSLCE) GC TO 100
      IF (NSCCN(K, 8).NE.NSCON(K3, 4)) GO TO 75
      MBA(K,1)=1
      MFB(K3,1)=1
75    IF (NSCCN(K, 9).NE.NSCON(K3, 5)) GC TO 80
      MBA(K,2)=1
      MFB(K3,2)=1
80    IF (NSCCN(K,10).NE.NSCON(K3, 6)) GO TO 85
      MBA(K,3)=1
```

```
      MFB(K3,3)=1
 85   IF (NSCON(K,11).NE.NSCON(K3, 7)) GO TO 100
      MBA(K,4)=1
      MFB(K3,4)=1
 100  K=K+1
 110  CONTINUE
C
C        ELEMENT CONNECTIVITY
C
      NC1=1
      KK=1
      MM1=1
      KKS=1
      MMS1=1
      II=0
      III=0
      MCB=0
      NF1=1
      MPB=0
      NP2=0
      NKIND=1
      DO 900 IS=1,NGSLCE
      NELGS(IS)=0
      IIIB=IS-1
      LS1=NSR(IS)
      IF (LS1.EQ.0) GO TO 890
      III=III+1
      DO 800 LS=1,LS1
      LLS1=1
      LLS2=2
      IF (LS.EQ.LS1) LLS1=LLS2
      DO 700 LLS=1,LLS1
      L4=0
      IF ((LS.EQ.1).AND.(LLS.EQ.1)) L4=1
      DO 500 I=1,NGCOL
      L1=NCR(IS,I)
      IF (L1.EQ.0) GO TO 470
      II=II+1
      DO 450 L=1,L1
      LL1=1
      LL2=2
      IF (L.EQ.L1) LL1=LL2
      DO 430 LL=1,LL1
      L3=0
      IF ((LL.EQ.1).AND.(L.EQ.1)) L3=1
      K=KK
      M1=MM1
      DO 400 J=1,NGROW
```

```
      IF (NSCCN(K,1).EQ.0) GO TO 390
      KA=K-1
      KB=K+1
      KL=K-NGRCW
      KL1=KL-1
      KL2=KL+1
      KR=K+NGRCW
      KR1=KR-1
      KBK=K-NGRCW*NGCOL
      KLBK=KL-NGROW*NGCOL
      DC 112 I7=1,4
      DC 112 I8=1,4
      MBK(I7,I8)=0
112   CCNTINUE
      DC 113 I7=1,4
      I8=I7+1
      IF (I7.EQ.4) I8=1
113   IF ((MFB(K,I7).EQ.1).AND.(MFB(K,I8).EQ.1)) MBK(I7,I8)=1
      GC TO (115,125),LLS
115   DC 118 MF1=1,8
118   MS(MF1)=MF(K,MF1)
      GC TO 130
125   DC 128 MF1=1,8
128   MS(MF1)=MB(K,MF1)
130   IF (LL.NE.LL2) GO TO 145
      GC TO (131,133),LLS
131   IF (((MS(7).EQ.0).AND.(MS(8).EQ.1)).AND.(MF(KA,6).EQ.1)) NC1=NC1-1
      GC TO 134
133   IF (((MS(7).EQ.0).AND.(MS(8).EQ.1)).AND.(MB(KA,6).EQ.1)) NC1=NC1-1
134   IF ((MS(6).EC.1).ANC.(MS(7).EQ.1)) GO TC 135
      GC TO 140
135   IF (((III.NE.1).AND.(L4.EQ.1)).ANC.(MBK(3,4).EQ.1)) GO TO 145
      M1=M1+NSCCN(K,1)
      GC TO 390
140   IF (MS(7).EQ.1) NC1=NC1-1
145   M2=M1+NSCCN(K,1)-1
      IF (M2.GT.MAXNEL) GC TO 980
      DC 350 M=M1,M2
      MMIN1=M-1
      MMIN1K=MMIN1-NRR(IS,I)
      IF (LL.NE.1) GO TO 148
      IF (L.NE.1) GO TO 147
      IF (M.EQ.M1) MEL(K,1)=M
      IF (M.EQ.M2) MEL(K,2)=M
147   IF (L.NE.L1) GO TO 148
      IF (M.EQ.M1) MEL(K,3)=M
      IF (M.EQ.M2) MEL(K,4)=M
148   DC 202 N=1,4
```

```
      NN=N
      IF (LLS.EQ.LLS2) NN=N+4
  202 NC(N)=NN
      N1=NC(1)
      N2=NC(2)
      N3=NC(3)
      N4=NC(4)
      GO TO (205,290),LL
  205 IF (MCB.NE.1) GO TO 206
      IF (((MFB(K,1).EQ.1).OR.(MFB(K,2).EQ.1)).AND.(L3.EQ.1)) GO TO 206
      IF (((MBK(4,1).EQ.1).OR.(MBK(2,3).EQ.1)).AND.(L3.EQ.0)) GO TO 206
      NCON(M,2)=NCON(MMIN1,3)
      NC1=NC1-1
      GO TO 207
  206 NCON(M,N2)=NC1
  207 NCON(M,N3)=NC1+1
      MCB=0
      IF ((III.NE.1).AND.(L4.EQ.1)) GO TO 208
      GO TO 260
  208 MBS4=MEL(KL2,3)
      IF (L.NE.1) GO TO 209
      IF ((((M.EQ.M2).AND.(MS(3).EQ.1)).AND.(MF(KL,5).EQ.1)).AND.
     1 (MFB(KL2,4).EQ.1)) NCON(M,3)=NCON(MBS4,1)
  209 IF ((MFB(K,1).EQ.0).AND.(MFB(K,2).EQ.0)) GO TO 230
      IF (M.NE.M1) GO TO 210
      IF (L.EQ.1) NELB(KBK)=MEL(KBK,1)
      MBS1=NELB(KBK)
  210 IF (L.NE.1) GO TO 250
      IF (MBK(1,2).NE.1) GO TO 212
      NCON(M,2)=NCON(MBS1,6)
      NCON(M,3)=NCON(MBS1,7)
      NC1=NC1-1
      IF ((MS(4).EQ.1).AND.(M.EQ.M2)) MCB=1
      IF ((MS(4).EQ.0).AND.(M.EQ.M2)) NC1=NC1-1
      GO TO 216
  212 IF (MFB(K,1).NE.1) GO TO 214
      IF (M.NE.M1) GO TO 216
      NCON(M,2)=NCON(MBS1,6)
      NCON(M,3)=NC1
      NC1=NC1-1
      GO TO 216
  214 IF (M.NE.M2) GO TO 218
      NCON(M,3)=NCON(MBS1,7)
      IF (MS(4).EQ.0) NC1=NC1-1
      IF (MS(4).EQ.1) MCB=1
      GO TO 218
  216 IF (M.NE.M1) GO TO 218
      IF (MF(K,1).EQ.1) NCON(MMIN1,3)=NCON(M,2)
```

```
218   MBS1=MBS1+1
      IF (M.EQ.M2) NELB(KBK)=NELB(KBK)+NRR(IIIB,I)
230   IF (L.NE.1) GO TO 260
      MBS6=MEL(KLBK,3)
      IF (M.EQ.M1) MBS3=MEL(KL,3)
      IF ((II.NE.1).AND.(M.EQ.M2)) MBS5=MEL(KLBK,4)
      IF ((MS(2).EQ.0).AND.(MS(3).EQ.0)) GO TO 260
      IF ((MFB(KL,3).EQ.0).AND.(MFB(KL,4).EQ.0)) GO TO 260
      IF ((MFB(K,1).EQ.1).OR.(MFB(K,2).EQ.1)) GO TO 260
      IF ((MFB(KL,3).EQ.1).AND.(MFB(KL,4).EQ.1)) GO TO 232
      GO TO 236
232   IF ((MS(2).EQ.1).AND.(MS(3).EQ.1)) GO TO 234
      GO TO 236
234   NCON(M,2)=NCON(MBS3,1)
      NCON(M,3)=NCON(MBS3,4)
      NC1=NC1-1
      IF ((MS(4).EQ.1).AND.(M.EQ.M2)) MCB=1
      IF ((MS(4).EQ.0).AND.(M.EQ.M2)) NC1=NC1-1
      GO TO 243
236   IF (((M.EQ.M1).AND.(MS(2).EQ.1)).AND.(MFB(KL,4).EQ.1)) GO TO 238
      GO TO 240
238   NCON(MBS3,1)=NCON(MBS6,5)
      NCON(M,2)=NCON(MBS3,1)
      NCON(M,3)=NC1
      NC1=NC1-1
      GO TO 243
240   IF (((M.EQ.M2).AND.(MS(3).EQ.1)).AND.(MFB(KL,3).EQ.1)) GO TO 241
      GO TO 243
241   NCON(MBS3,4)=NCON(MBS5,8)
      NCON(M,3)=NCON(MBS3,4)
242   IF (M.NE.M2) GO TO 244
      IF (MS(4).EQ.0) NC1=NC1-1
      IF (MS(4).EQ.1) MCB=1
      GO TO 244
243   IF (M.NE.M1) GO TO 244
      IF (MF(K,1).EQ.1) NCON(MMIN1,3)=NCON(M,2)
244   MBS3=MBS3+1
      GO TO 260
250   IF ((MBK(4,1).EQ.1).AND.(MBK(2,3).EQ.1)) GO TO 251
      GO TO 252
251   NCON(M,2)=NCON(MBS1,6)
      NCON(M,3)=NCON(MBS1,7)
      NC1=NC1-1
      IF (((MS(4).EQ.1).AND.(MS(5).EQ.1)).AND.(M.EQ.M2)) MCB=1
      IF ((MS(4).EQ.0).AND.(M.EQ.M2)) NC1=NC1-1
      GO TO 256
252   IF (MBK(4,1).NE.1) GO TO 254
      IF (M.NE.M1) GO TO 256
```

```
      NCCN(M,2)=NCON(MBS1,6)
      NCCN(M,3)=NC1
      NC1=NC1-1
      GC TO 256
254   IF (MBK(2,3).NE.1) GO TO 258
      IF (M.NE.M2) GO TO 258
      NCON(M,3)=NCON(MBS1,7)
      IF (MS(4).EQ.0) NC1=NC1-1
      IF ((MS(4).EQ.1).AND.(MS(5).EQ.1)) MCB=1
      GC TO 258
256   IF (M.NE.M1) GO TO 258
      IF ((MF(K,1).EQ.1).AND.(MF(K,8).EQ.1)) GC TC 257
      GC TO 258
257   NCCN(MMIN1,3)=NCCN(M,2)
      NCCN(MMIN1K,4)=NCON(M,2)
258   MBS1=MBS1+1
      IF (M.EQ.M2) NELB(KBK)=NELB(KBK)+NRR(IIIB,I)
260   IF (L.EQ.1) GO TO 265
      NCCN(MM2,N1)=NCON(M,N2)
      NCCN(MM2,N4)=NCON(M,N3)
      MM2=MM2+1
      GC TO 300
265   IF(II.EC.1) GO TC 300
      IF ((MS(2).EQ.0).AND.(MS(3).EQ.0)) GO TO 30C
      IF (M.NE.M1) GO TC 270
      MM3=MEL(KL,3)
      MM4=MEL(K,1)
27C   IF ((MS(2).EQ.1).ANC.(MS(3).EQ.1)) GO TO 275
      GC TO 3C0
275   NCCN(MM3,N1)=NCON(MM4,N2)
      NCCN(MM3,N4)=NCON(MM4,N3)
      MM3=MM3+1
      MM4=MM4+1
      GC TO 3C0
290   NCCN(M,N1)=NC1
      NCCN(M,N4)=NC1+1
      IF ((III.NE.1).AND.(L4.EQ.1)) GC TC 291
      GC TO 300
291   IF ((MFB(K,3).EQ.0).ANC.(MFB(K,4).EQ.0)) GC TC 300
      IF (M.EQ.M1) MBS1=MEL(KBK,3)
      IF (MBK(3,4).NE.1) GO TO 292
      NCCN(M,1)=NCCN(MBS1,5)
      NCCN(M,4)=NCON(MBS1,8)
      NC1=NC1-1
      IF(((MS(5).EQ.0).AND.(M.EQ.M2)).AND.(MS(6).NE.1)) NC1=NC1-1
      IF (M.NE.M1) GO TO 294
      IF ((MS(7).EQ.1).AND.(MS(6).EQ.0)) NC1=NC1+1
      IF (((MS(7).EQ.0).AND.(MS(8).EQ.1)).AND.(MF(KA,6).EQ.1)) NC1=NC1+1
```

```
      GO TO 294
292   IF (MFB(K,4).NE.1) GO TO 293
      IF (M.NE.M1) GO TO 294
      NCON(M,1)=NCON(MBS1,5)
      IF ((MS(7).EQ.1).AND.(MS(6).EQ.0)) NC1=NC1+1
      IF (((MS(7).EQ.0).AND.(MS(8).EQ.1)).AND.(MF(KA,6).EQ.1)) NC1=NC1+1
      NCON(M,4)=NC1
      NC1=NC1-1
      GO TO 294
293   IF (MFB(K,3).NE.1) GO TO 295
      IF (M.NE.M2) GO TO 295
      NCON(M,4)=NCON(MBS1,8)
      IF (MS(5).EQ.0) NC1=NC1-1
      GO TO 295
294   IF (M.NE.M1) GO TO 295
      IF (MF(K,8).EQ.1) NCON(MMIN1,4)=NCON(M,1)
295   MBS1=MBS1+1
300   NC1=NC1+1
      NCON(M,9)=NSCON(K,12)
350   CONTINUE
      IF ((II.NE.1).AND.(L3.EQ.1)) GO TO 355
      GO TO 375
355   IF ((MS(2).EQ.0).AND.(MS(3).EQ.0)) GO TO 375
      MM5=MEL(K,2)
      MM6=MEL(KL,4)
      MM7=MEL(KL1,4)
      MM8=MEL(KL2,3)
      MM9=MEL(KL,3)
      MM10=MEL(K,1)
360   IF (MS(2).NE.1) GO TO 362
      NCON(MM9,N1)=NCON(MM10,N2)
      IF ((MF(KL,8).EQ.1).AND.(MB(KL,8).EQ.1)) NCON(MM7,N4)=NCON(MM9,N1)
362   IF (MS(3).NE.1) GO TO 375
      NCON(MM6,N4)=NCON(MM5,N3)
      IF ((MF(KL,5).EQ.1).AND.(MB(KL,5).EQ.1)) NCON(MM8,N1)=NCON(MM6,N4)
375   IF ((   MS(4).EQ.0).AND.(L3.EQ.1)) NC1=NC1+1
      IF (((   MS(4).EQ.0).OR.(   MS(5).EQ.0)).AND.(L3.EQ.0))
     1.AND.(LL.NE.LL2)) NC1=NC1+1
      IF (((   MS(5).EQ.0).AND.(   MS(6).NE.1)).AND.(LL.EQ.LL2)) NC1=NC1+1
380   M1=M2+1
390   K=K+1
400   CONTINUE
430   CONTINUE
      MM2=MM1
      MM1=M1
450   CONTINUE
      KK=K
      GO TO 500
```

```
470   KK=KK+NGROW
500   CCNTINUE
      KK=KKS
      II=0
      IF ((LLS.EQ.1).AND.(LS.NE.1)) GC TC 505
      GC TO 530
505   DC 520 M=MMS1,M2
      DC 510 IC=1,4
      IC1=IC+4
510   NCCN(MMS2,IC1)=NCCN(M,IC)
520   MMS2=MMS2+1
530   IF (LLS.NE.LLS1) MM1=MMS1
700   CCNTINUE
      MMS2=MMS1
      MMS1=M1
      NP1B=NP1-1
      IF (NP1.NE.1) MPB=NELP(NP1B)
      NP2=NP2+MPB
      NELP(NP1)=M-NP2
      NELGS(IS)=NELGS(IS)+NELP(NP1)
      NP1=NP1+1
800   CCNTINUE
890   KKS=KKS+NGROW*NGCOL
      KK=KKS
900   CCNTINUE
      NEL=M
      NJT=NCCN(NEL,8)
      WRITE (6,13) NEL,NJT
      IF (NJT.GT.MAXNJT) GO TO 990
      WRITE (6,10)
      NBAND=0
      DC 950 I=1,NEL
      MAXB=0
      MINB=MAXNJT+1
      DC 910 J=1,4
910   IF (NCON(I,J).LT.MINB) MINB=NCON(I,J)
      DC 920 K=5,8
920   IF (NCON(I,K).GT.MAXB) MAXB=NCON(I,K)
      NBAND1=MAXB-MINB
      IF (NBAND1.GT.NBAND) NBAND=NBAND1
      IF(NPUNCH.EQ.0) GC TO 950
      WRITE (7,11) (NCON(I,IN),IN=1,9)
950   WRITE (6,12) I,(NCCN(I,IN),IN=1,9)
      NBAND=(NBAND+1)*3
      WRITE (6,975) NBAND
975   FCRMAT (///,' HALF BAND WIDTH FCR TRISOP STIFFNESS MATRIX=',I5)
      RETURN
980   NSTCP=1
```

```
      WRITE (6,985) MAXNEL
  985 FORMAT (///,' DATA REJECTED***NUMBER OF ELEMENTS GREATER THAN',I5
     1,/,' ************************************************************')
      RETURN
  990 NSTOP=1
      WRITE (6,995) MAXNJT
  995 FORMAT (///,' DATA REJECTED***NUMBER OF JOINTS GREATER THAN',I5
     1,/,' ************************************************************')
      RETURN
      END



      SUBROUTINE COORD
C
C        THIS SUBROUTINE DETERMINES X,Y&Z COORDINATES OF JOINTS.
C        OUTPUT IS PRINTED WITH AN OPTION TO PUNCH IN FORMAT
C        COMPATIBLE WITH 'TRISOP'.
C
      IMPLICIT REAL*8 (A-H,O-Z)
      IMPLICIT INTEGER*2 (I-N)
      DIMENSION NL1(4),NL2(4),NL3(4),NL4(4),NL5(4),NL6(4)
      DIMENSION XI(8),ETA(8),ZETA(8)
      COMMON/INT/NPT,NEL,NPUNCH,NSTOP,NJT,NPLOT,NKIND,NSEL,NGROW,NGCOL,
     1NGSLCE
      COMMON/MESH1/ NSCON(125,13), MF(125,8), MB(125,8), MFB(125,4),
     1MBA(125,4),  MEL(125,4),  NELB(125),  NELF(125)
      COMMON/MESH2/ NRR(5,5),NCR(5,5),NSR(5),NELGS(5)
      COMMON/MESH3/ NCON(200,9)
      COMMON/CORD1/CORD(1296,3)
      COMMON/CORD2/BOUND(200,3)
      COMMON/SF/ VAL(32)
      DATA NL1/2,3,6,7/
      DATA NL2/1,4,5,8/
      DATA NL3/1,2,5,6/
      DATA NL4/3,4,7,8/
      DATA NL5/1,2,3,4/
      DATA NL6/5,6,7,8/
   20 FORMAT (///,' COORDINATES OF JOINTS',//,' JOINT NUMBER',8X,
     1'X COORDINATE',5X,'Y COORDINATE',5X,'Z COORDINATE',//)
   30 FORMAT (5X,I3,12X,G14.5,2(3X,G14.5))
   40 FORMAT (6X,I10,3F15.5)
C
C
      LL=1
      J1=1
```

```
      K=1
C
C        GRID SLICE
C
      CC 900 L=1,NGSLCE
      IF (NSR(L).EC.0) GC TO 890
      J2=J1+NSR(L)-1
C
C        GRID COLUMN
C
      CC 800 NK=1,NGCOL
      IF (NCR(L,NK).EQ.0) GO TO 790
C
C        GRID RCW
C
      CC 700 M=1,NGROW
      IF (NSCCN(K,1).EQ.0) GC TO 700
      NPTB=NSCCN(K,13)
      CELXI =2.DO/(1*NSCON(K,2))
      CELETA=2.CO/(1*NSCCN(K,1))
      CELZET=2.CC/(1*NSCCN(K,3))
      XIVAL =-1.DO
      ETAVAL=1.DO
      ZETVAL=1.DC
      N2=NSCON(K,2)
C
C        SUPER ELEMENT SLICE
C
      DC 600 J=J1,J2
      IF (J.NE.J1) GO TO 5C
      NK1=MEL(K,1)-NELGS(L)+NELP(J)
      I1=NK1
C
C        SUPER ELEMENT COLUMNS
C
 50   CC 500 N=1,N2
      I2=I1+NSCCN(K,1)-1
C
C        SUPER ELEMENT ROWS
C
      DC 400 I=I1,I2
      CC 100 MM=1,4
      L1=NL1(MM)
 100  XI(L1)=XIVAL
      CC 120 MM=1,4
      L1=NL2(MM)
 12C  XI(L1)=XIVAL+DELXI
      CC 160 MM=1,4
```

```
      L1=NL3(MM)
16C   ETA(L1)=ETAVAL
      DC 180 MM=1,4
      L1=NL4(MM)
18C   ETA(L1)=ETAVAL-DELETA
      CC 220 MM=1,4
      L1=NL5(MM)
22C   ZETA(L1)=ZETVAL
      CC 240 MM=1,4
      L1=NL6(MM)
240   ZETA(L1)=ZETVAL-DELZET
      CC 350 MM=1,8
      L2=NCON(I,MM)
      XI1=XI(MM)
      ETA1=ETA(MM)
      ZETA1=ZETA(MM)
      CALL SHAPE (XI1,ETA1,ZETA1,NPTB)
      CCRC(L2,1)=0.DO
      CCRD(L2,2)=0.DO
      CCRD(L2,3)=0.DO
      LLL=LL
      DC 300 NN=1,NPTB
      CCRD(L2,1)=CORD(L2,1)+VAL(NN)*BOUND(LLL,1)
      CCRD(L2,2)=CGRD(L2,2)+VAL(NN)*BOUNC(LLL,2)
      CCRD(L2,3)=CCRD(L2,3)+VAL(NN)*BCUND(LLL,3)
300    LLL=LLL+1
350   CCNTINUE
      ETAVAL=ETAVAL-DELETA
400   CCNTINUE
      ETAVAL=1.DO
      I1=I1+NRR(L,NK)
      XIVAL=XIVAL+DELXI
50C   CCNTINUE
      XIVAL=-1.DC
      NK1=NK1+NELP(J)
      I1=NK1
      ZETVAL=ZETVAL-DELZET
60C   CCNTINUE
      ZETVAL=1.DO
      LL=LL+NPTB
70C   K=K+1
      GC TO 8CO
79C   K=K+NGRCW
800   CCNTINUE
      J1=J2+1
      GC TO 900
890   K=K+NGRCW*NGCOL
90C   CCNTINUE
```

```
      WRITE (6,20)
      DO 950 I=1,NJT
      IF (NPUNCH.EQ.0) GO TO 950
      WRITE (7,40) I,(CORD(I,J),J=1,3)
  950 WRITE (6,30) I,(CORD(I,J),J=1,3)
      RETURN
      END



      SUBROUTINE SHAPE (X,Y,Z,NBNCDE)
      IMPLICIT REAL*8 (A-H,O-Z)
      DIMENSION XYZL(8,3),XYZQ(20,3),XYZC(32,3),IPERM(16)
      COMMON/SF/VAL(32)
      DATA XYZL/1.0D0,-1.0D0,-1.0D0,1.0D0,1.0D0,-1.0D0,-1.0D0,1.0D0,
     11.0D0,1.0D0,-1.0D0,-1.0D0,1.0D0,1.0D0,-1.0D0,-1.0D0,1.0D0,1.0D0,
     21.0D0,1.0D0,-1.0D0,-1.0D0,-1.0D0,-1.0D0/
      DATA XYZQ/1.0D0,0.0D0,-1.0D0,-1.0D0,-1.0D0,0.0D0,1.0D0,1.0D0,
     11.0D0,-1.0D0,-1.0D0,1.0D0,1.0D0,0.0D0,-1.0D0,-1.0D0,-1.0D0,0.0D0,
     21.0D0,1.0D0,1.0D0,1.0D0,1.0D0,0.0D0,-1.0D0,-1.0D0,-1.0D0,0.0D0,
     31.0D0,1.0D0,-1.0D0,-1.0D0,1.0D0,1.0D0,1.0D0,0.0D0,-1.0D0,-1.0D0,
     4-1.0D0,0.0D0,1.0D0,1.0D0,1.0D0,1.0D0,1.0D0,1.0D0,1.0D0,1.0D0,
     50.0D0,0.0D0,0.0D0,0.0D0,-1.0D0,-1.0D0,-1.0D0,-1.0D0,-1.0D0,-1.0D0,
     6-1.0D0,-1.0D0/
      DATA XYZC/1.0D0,.3333333333333333D0,-.3333333333333333D0,-1.0D0,
     1-1.0D0,-1.0D0,-1.0D0,-.3333333333333333D0,.3333333333333333D0,
     21.0D0,1.0D0,1.0D0,1.0D0,-1.0D0,-1.0D0,1.0D0,1.0D0,-1.0D0,-1.0D0,
     31.0D0,1.0D0,.3333333333333333D0,-.3333333333333333D0,-1.0D0,-1.0D0,
     4-1.0D0,-1.0D0,-.3333333333333333D0,.3333333333333333D0,1.0D0,1.0D0,
     51.0D0,1.0D0,1.0D0,1.0D0,1.0D0,.3333333333333333D0,
     6-.3333333333333333D0,-1.0D0,-1.0D0,-1.0D0,-1.0D0,
     7-.3333333333333333D0,.3333333333333333D0,1.0D0,1.0D0,-1.0D0,-1.0D0,
     81.0D0,1.0D0,-1.0D0,-1.0D0,1.0D0,1.0D0,1.0D0,1.0D0,
     9.3333333333333333D0,-.3333333333333333D0,-1.0D0,-1.0D0,-1.0D0,
     A-1.0D0,-.3333333333333333D0,.3333333333333333D0,1.0D0,1.0D0,1.0D0,
     B1.0D0,1.0D0,1.0D0,1.0D0,1.0D0,1.0D0,1.0D0,1.0D0,1.0D0,
     C.3333333333333333D0,.3333333333333333D0,.3333333333333333D0,
     D.3333333333333333D0,-.3333333333333333D0,-.3333333333333333D0,
     E-.3333333333333333D0,-.3333333333333333D0,-1.0D0,-1.0D0,-1.0D0,
     F-1.0D0,-1.0D0,-1.0D0,-1.0D0,-1.0D0,-1.0D0,-1.0D0,-1.0D0,-1.0D0/
      DATA IPERM/2,3,8,9,22,23,28,29,5,6,11,12,25,26,31,32/
      FL (X,Y,Z,X1,Y1,Z1) = (1.0D0+X*X1)*(1.0D0+Y*Y1)*(1.0D0+Z*Z1)/.8D1
      FCC(X,Y,Z,X1,Y1,Z1) = (1.0D0+X*X1)*(1.0D0+Y*Y1)*(1.0D0+Z*Z1)*
     1(X*X1+Y*Y1+Z*Z1-.2D1)/.8D1
      FCM(X,Y,Z,    Y1,Z1) = (1.0D0-X*X)*(1.0D0+Y*Y1)*(1.0D0+Z*Z1)/.4D1
      FCC(X,Y,Z,X1,Y1,Z1) = (1.0D0+X*X1)*(1.0D0+Y*Y1)*(1.0D0+Z*Z1)*
```

```
     1(.9D1*(X*X+Y*Y+Z*Z)-1.9D1)/6.4D1
      FCM(X,Y,Z,X1,Y1,Z1) = (1.0D0-X*X)*(1.0D0+.9D1*X*X1)*(1.0D0+Y*Y1)*
     1(1.0D0+Z*Z1)*.9D1/6.4D1
      IF (NBNODE.EQ.32) GC TO 500
      IF (NBNCDE.EQ.20) GC TO 200
C
C        LINEAR FUNCTIONS
C
      DC 100 I=1,8
      X1=XYZL(I,1)
      Y1=XYZL(I,2)
      Z1=XYZL(I,3)
  100 VAL(I)=FL(X,Y,Z,X1,Y1,Z1)
      RETURN
C
C        QUADRATIC FUNCTICNS
C
  200 DC 250 I=1,7,2
      J=I+12
      X1=XYZQ(I,1)
      Y1=XYZQ(I,2)
      Z1=XYZQ(I,3)
      X2=XYZQ(J,1)
      Y2=XYZQ(J,2)
      Z2=XYZQ(J,3)
      VAL(I)=FQC(X,Y,Z,X1,Y1,Z1)
  250 VAL(J)=FQC(X,Y,Z,X2,Y2,Z2)
      DC 300 I=2,6,4
      J=I+12
      Y1=XYZQ(I,2)
      Z1=XYZQ(I,3)
      Y2=XYZQ(J,2)
      Z2=XYZQ(J,3)
      VAL(I)=FQM(X,Y,Z,Y1,Z1)
  300 VAL(J)=FQM(X,Y,Z,Y2,Z2)
      DC 350 I=4,8,4
      J=I+12
      X1=XYZQ(I,1)
      Z1=XYZQ(I,3)
      X2=XYZQ(J,1)
      Z2=XYZQ(J,3)
      VAL(I)=FQM(Y,Z,X,Z1,X1)
  350 VAL(J)=FQM(Y,Z,X,Z2,X2)
      DC 400 I=9,12
      X1=XYZQ(I,1)
      Y1=XYZQ(I,2)
  400 VAL(I)=FQM(Z,X,Y,X1,Y1)
      RETURN
```

```
C
C          CUBIC FUNCTIONS
C
 50C  DC 550  I=1,10,3
      J=I+20
      X1=XYZC(I,1)
      Y1=XYZC(I,2)
      Z1=XYZC(I,3)
      X2=XYZC(J,1)
      Y2=XYZC(J,2)
      Z2=XYZC(J,3)
      VAL(I)=FCC(X,Y,Z,X1,Y1,Z1)
 55C  VAL(J)=FCC(X,Y,Z,X2,Y2,Z2)
      CC 600  I=1,8
      II=IPERM(I)
      X1=XYZC(II,1)
      Y1=XYZC(II,2)
      Z1=XYZC(II,3)
 600  VAL(II)=FCM(X,Y,Z,X1,Y1,Z1)
      CC 650  I=9,16
      II=IPERM(I)
      X1=XYZC(II,1)
      Y1=XYZC(II,2)
      Z1=XYZC(II,3)
 650  VAL(II)=FCM(Y,Z,X,Y1,Z1,X1)
      CC 700  I=13,20
      X1=XYZC(I,1)
      Y1=XYZC(I,2)
      Z1=XYZC(I,3)
 700  VAL(I)=FCM(Z,X,Y,Z1,X1,Y1)
      RETURN
      END
```

```
      SUBROUTINE TRFR(TETA,ALPHA,BETA)
      IMPLICIT REAL*8 (A-H,O-Z)
      IMPLICIT INTEGER*2 (I-N)
      COMMON/INT/NPT,NEL,NPUNCH,NSTOP,NJT,NPLOT,NKIND,NSEL,NGROW,NGCOL,
     1NGSLCE
      COMMON/CORD1/CORD(1296,3)
      DIMENSION TFORM(3,3),DUM(3)
      CTET=DCOS(TETA)
      STET=DSIN(TETA)
      CALP=DCOS(ALPHA)
      SALP=DSIN(ALPHA)
      CBET=DCOS(BETA)
      SBET=DSIN(BETA)
      TFORM(1,1)=CTET*CBET-SALP*STET*SBET
      TFORM(1,2)=STET*CBET+SALP*CTET*SBET
      TFORM(1,3)=-SBET*CALP
      TFORM(2,1)=-STET*CALP
      TFORM(2,2)=CALP*CTET
      TFORM(2,3)=SALP
      TFORM(3,1)=SBET*CTET+STET*SALP*CBET
      TFORM(3,2)=STET*SBET-SALP*CTET*CBET
      TFORM(3,3)=CALP*CBET
      DO 300 I=1,NJT
      DO 100 J=1,3
      DUM(J)=0.0D0
      DO 100 K=1,3
  100 DUM(J)=DUM(J)+TFORM(J,K)*CORD(I,K)
      DO 200 J=1,3
  200 CORD(I,J)=DUM(J)
  300 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE GRID
      IMPLICIT REAL*8 (A-H,O-Z)
      IMPLICIT INTEGER*2 (I-N)
      INTEGER*4 N1,MC,ITYPE,IXUP,IYRT,MDXAX,MDYAX,IWIDE,IHIGH,IGRID,LAST
      INTEGER*4 NJJ
      REAL*4 X,Y,XSCALE,YSCALE
      REAL LABEL/4H    /
      DIMENSION X(9), Y(9), ISIX(2,3)
      DIMENSION NPL(2),INCL(2)
      COMMON/TITL/TITLE(12)
      COMMON/MESH3/ NCON(200,33)
      COMMON/INT/NPT,NEL,NPUNCH,NSTOP,NJT,NPLOT,NKIND,NSEL,NGROW,NGCOL,
     1NGSLCE
      COMMON/CORD1/CORD(1296,3)
      DATA ISIX/1,2,2,3,3,1/
      DATA NPL/1,5/
      DATA INCL/1,1/
      DATA ITYPE/0/  ,IXUP/15/,IYRT/0/  ,MDXAX/2/  ,MDYAX/2/  ,IWIDE/9/  ,
     1IHIGH/15/  ,IGRID/0/
      NKIND=1
      NPT=8
      DO 180 II=1,3
      XMAX=-1.0D+20
      YMAX=-1.0D+20
      XMIN= 1.0D+20
      YMIN= 1.0D+20
      I1=ISIX(1,II)
      I2=ISIX(2,II)
      DO 20 I=1,NJT
      XMAX=DMAX1(XMAX,CORD(I,I1))
      YMAX=DMAX1(YMAX,CORD(I,I2))
      XMIN=DMIN1(XMIN,CORD(I,I1))
 20   YMIN=DMIN1(YMIN,CORD(I,I2))
      IF (XMIN.GE.0.D0) GO TO 40
      XMAX=XMAX-XMIN
      DO 30 I=1,NJT
 30   CORD(I,I1)=CORD(I,I1)-XMIN
 40   IF (YMIN.GE.0.D0) GO TO 60
      YMAX=YMAX-YMIN
      DO 50 I=1,NJT
 50   CORD(I,I2)=CORD(I,I2)-YMIN
   60 CONTINUE
 110  XSCALE=1.5D0*(YMAX/9.D0)
      YSCALE=1.5D0*(XMAX/15.D0)
      IF (XSCALE.GT.YSCALE) YSCALE=XSCALE
      IF (XSCALE.LT.YSCALE) XSCALE=YSCALE
      N1=(NPT+4)/3 + 1
      MC=1
```

```
      MSTOP=0
      DO 170 I=1,NEL
      IF (I.EQ.NEL) MSTOP=3
C
      JT=N1-1
      DO 120 J=1,JT
      J1=NCON(I,J)
      IF (J.EQ.1) J2=J1
      X(J)=CORD(J1,I2)
  120 Y(J)=-CORD(J1,I1)
      J=J+1
      X(J)=CORD(J2,I2)
      Y(J)=-CORD(J2,I1)
      CALL DRAW (N1,X ,Y ,MC,ITYPE,LABEL,TITLE,XSCALE,YSCALE,IXUP,IYRT,
     1MDXAX,MDYAX,IWIDE,IHIGH,IGRID,LAST)
      MC=2
      JL=2*JT-3
      JTT=JL+JT-1
      DO 130 J=JL,JTT
      J1=NCON(I,J)
      IF (J.EQ.JL) J2=J1
      M=J-JL+1
      X(M)=CORD(J1,I2)
  130 Y(M)=-CORD(J1,I1)
      M=M+1
      X(M)=CORD(J2,I2)
      Y(M)=-CORD(J2,I1)
      CALL DRAW (N1,X ,Y ,MC,ITYPE,LABEL,TITLE,XSCALE,YSCALE,IXUP,IYRT,
     1MDXAX,MDYAX,IWIDE,IHIGH,IGRID,LAST)
      DO 160 JJJ=1,4
      JJ1=NKIND+1
      DO 150 JJ=1,JJ1
      J1=NPL(JJ)+INCL(JJ)*(JJJ-1)
      IF((MSTOP.EQ.3).AND.(JJJ.EQ.4))  MC=3
      JX=NCON(I,J1)
      X(JJ)=CORD(JX,I2)
  150 Y(JJ)=-CORD(JX,I1)
      NJJ=JJ
      CALL DRAW(NJJ,X ,Y ,MC,ITYPE,LABEL,TITLE,XSCALE,YSCALE,IXUP,IYRT,
     1MDXAX,MDYAX,IWIDE,IHIGH,IGRID,LAST)
  160 CONTINUE
  170 CONTINUE
  180 CONTINUE
      RETURN
      END
```

APPENDIX G

COMPUTER LISTING (TRIMEG-2)

```
C                                    ************
C                                    * TRIMEG-2 *
C                                    ************
C
      IMPLICIT REAL*8 (A-H,O-Z)
      IMPLICIT INTEGER*2 (I-N)
      DIMENSION NCT(200)
      COMMON/TITL/TITLE(12)
      COMMON/INT/NPT,NEL,NPUNCH,NSTOP,NJT,NPLOT,NKIND,NSEL,NGROW,NGCOL,
     1NGSLCE
      COMMON/MESH1/ NSCON(125,13), MF(125,8), ME(125,8), MFB(125,4),
     1MBA(125,4),  MEL(125,4),  NELB(125),  NELF(125)
C
C
      COMMON/CORD1/CORD(1296,3)
      COMMON/CORD2/BOUND(200,3)
C
C
      DATA MAXBJT/200/
      NGROW=5
      NGCOL=5
      NGSLCE=5
C
C        NGROW, NGCOL AND NGSLCE ARE MAX NO. OF SUPER ELEMENT ROWS,
C        COLUMNS AND SLICES RESPECTIVELY.
C
C        MESH1 COMMON ENTRIES DIMENSIONED (I,*),
C        WHERE I=(NGROW+1)*NGCOL*(NGSLCE+1)
C
C        MESH1 ALSO CONTAINED IN SUBROUTINES CONN, COORD, AND GRID.
C
C        CORD1 COMMON ENTRIES DIMENSIONED MAX JOINTS IN "TRISOP".
C
C        CORD1 ALSO CONTAINED IN SUBROUTINES COORD AND GRID.
C
C        CORD2 COMMON ENTRY DIMENSIONED (I,3) AND NCT DIMENSIONED (I),
C        WHERE I=MAXBJT ABOVE. THIS IS ARBITRARY.
C
C        CORD2 ALSO CONTAINED IN SUBROUTINE COORD.
C
  5   READ (5,10,END=9000) (TITLE(I),I=1,6)
      READ (5,10) (TITLE(I),I=7,12)
      WRITE (6,20) (TITLE(I),I=1,6)
      WRITE (6,22) (TITLE(I),I=7,12)
      READ (5, 9) NSEL,NPUNCH,NPLOT,TETA,ALPHA,BETA
      WRITE (6,35)
      WRITE (6,33) NSEL,NPUNCH,NPLOT,TETA,ALPHA,BETA
  9   FORMAT (3I5,3F5.0)
```

```
10    FORMAT (6A8)
11    FORMAT (14I5)
20    FORMAT ('1',6A8)
22    FORMAT (1X,6A8)
25    FORMAT (3I5,3F20.0)
28    FORMAT (4X,I3,6X,I3,5X,I3,3(3X,G25.15))
30    FORMAT (//,' BOUNDARY DATA',//,'    SEL NO.',2X,'NODE NO.',2X,
     1'NCT',9X,'X COORDINATE',16X,'Y COORDINATE',16X,'Z COORDINATE',//)
31    FORMAT (10X,I3,8X,12(I3,3X),I3)
33    FORMAT (10X,I3,3X,I3,6X,I3,4X,3F7.2)
34    FORMAT (///,' SUPER ELEMENT DATA',//,9X,'SEL NO.',6X,'ROW',
     1'    COL   SLICE   (A)     (B)     (C)     (D)     (E)     (F)     (G)     (H)   TYP
     2E   NPTSB',/)
35    FORMAT (///,' MESH PARAMETERS',//,10X,'NSEL   NPUNCH    NPLOT',4X,
     1  'TETA',3X,'ALPHA',3X,'BETA',/)
      PI=3.141592654D0
      TETA=TETA*PI/180.0D0
      ALPHA=ALPHA*PI/180.0D0
      BETA=BETA*PI/180.0D0
      NSTOP=0
      K=1
      DO 40 MM=1,NGSLCE
      DO 40 I=1,NGCOL
      DO 39 J=1,NGROW
      DO 36 L=1,13
36    NSCON(K,L)=0
      DO 37 M=1,8
      MF(K,M)=0
      MB(K,M)=0
37    MEL(K,M)=0
      DO 38 N=1,4
      MFB(K,N)=0
38    MBA(K,N)=0
39    K=K+1
40    CONTINUE
C
C        SUPER ELEMENT DATA
C
      NPTSBT=0
      WRITE (6,34)
      DO 60 N=1,NSEL
      IF (NPTSBT.GT.MAXBJT) NSTOP=2
      READ (5,11)   I,(NSCON(I,J),J=1,13)
      WRITE (6,31)  I,(NSCON(I,J),J=1,13)
60    NPTSBT=NPTSBT+NSCON(I,13)
C
C        BOUNDARY DATA
C
```

```
      WRITE (6,30)
      NLIN=0
      NBS1=0
      DC 70 I=1,NPTSBT
      READ (5,25)   NBSEL,NBNODE,NCT(I),(BOUND(I,J),J=1,3)
      IF (NBSEL.LT.NBS1) NSTCP=1
      NBS1=NBSEL
      IF (NCT(I).GT.0) NLIN=1
   70 WRITE (6,28)  NBSEL,NBNODE,NCT(I),(BOUND(I,J),J=1,3)
      IF (NSTCP.EQ.1) GO TO 170
      IF (NSTCP.EQ.2) GO TO 180
C
C        STRAIGHT BOUNDARY MID-SIDE NCDES
C
      IF (NLIN.EQ.0) GO TC 190
      K=1
      NSELT=NGCCL*NGROW*NGSLCE
      DC 160 J=1,NSELT
      IF (NSCCN(J,1).EQ.C) GO TO 160
      IF (NSCCN(J,13).EG.  8) GO TO 155
      NPT1=NSCON(J,13)
      DC 150 I=1,NPT1
      IF (NSCCN(J,13).EG.32) GO TC 120
      IF (NCT(K).NE.1) GC TO 150
      IF ((I.GE.9).AND.(I.LE.12)) GO TC 100
      M=K-1
      N=K+1
      IF ((I.EQ.8).OR.(I.EQ.20)) N=K-7
      GC TO 110
  100 I1=I-8
      GC TO (102,104,106,108),I1
  102 M=K-8
      N=K+4
      GC TO 110
  104 M=K-7
      N=K+5
      GC TO 110
  106 M=K-6
      N=K+6
      GC TO 110
  108 M=K-5
      N=K+7
  110 BCUND(K,1)=(BOUND(M,1)+BOUND(N,1))/2.0D0
      BCUND(K,2)=(BCUND(M,2)+BCUND(N,2))/2.0D0
      BCUND(K,3)=(BCUND(M,3)+BOUNC(N,3))/2.0D0
      GC TO 150
  120 IF (NCT(K).NE.2) GC TC 150
      IF ((I.GE.13).AND.(I.LE.20)) GO TC 130
```

```
      K1=K+1
      I1=I+1
      IF ((NCT(K1).NE. 2).OR.(I1.EQ.13)) GO TO 150
      M=K-1
      N=K+2
      IF ((I.EQ.11).OR.(I.EQ.31)) N=K-10
       GC TO 144
130   K1=K+4
      I1=I+4
      IF (I1.GT.20) GO TO 150
      I2=I-12
      GC TO (137,139,141,143),I2
137   M=K-12
      N=K+8
      GC TO 144
139   M=K-10
      N=K+10
      GC TO 144
141   M=K-8
      N=K+12
      GC TO 144
143   M=K-6
      N=K+14
144   BMIDX=BCUND(M,1)-BCUND(N,1)
      BMIDY=BCUND(M,2)-BCUND(N,2)
      BMIDZ=BCUND(M,3)-BCUND(N,3)
      BCUND(K,1)=BOUND(M,1)-BMIDX/3.0D0
      BCUND(K,2)=BOUND(M,2)-BMIDY/3.0D0
      BCUND(K,3)=BCUND(M,3)-BMIDZ/3.0D0
      BCUND(K1,1)=BOUND(M,1)-2*BMIDX/3.0D0
      BCUND(K1,2)=BOUND(M,2)-2*BMIDY/3.0D0
      BCUND(K1,3)=BOUND(M,3)-2*BMIDZ/3.0D0
150   K=K+1
      GC TO 160
155   K=K+8
160   CCNTINUE
      GC TO 190
170   WRITE (6,175)
175   FCRMAT (///,'  DATA REJECTED***SUPER ELEMENT NUMBERS NOT IN ASCEND
     1ING CRDER FOR BOUNDARY INPUT DATA.',/,
     2'****************************************************',///)
      GC TO 5
180   WRITE (6,185) MAXBJT
185   FCRMAT (///,'  DATA REJECTED***NUMBER OF BOUNDARY NODES GREATER TH
     1AN',I5,/,'****************************************************',/)
      GC TO 5
190   NSTCP=0
      CALL CCNN
```

```
      IF (NSTCP.EQ.1) GC TO 5
      CALL COCRD
      IF (NPLCT.NE.1) GO TO 5
      CALL TRFR(TETA,ALPHA,BETA)
      CALL GRID
      GC TO 5
 9CCO STOP
      ENC




      SLBROUTINE CONN
C
C        THIS SUBROUTINE DETERMINES ELEMENT CONNECTIVITY. OUTPUT IS
C        PRINTED WITH OPTICN TO PUNCH IN FORMAT CCMPATIBLE WITH "TRISCP"
C
      IMPLICIT REAL*8 (A-H,C-Z)
      IMPLICIT INTEGER*2 (I-N)
      DIMENSICN MS(8),NC(8),MBK(4,4)
      CCMMON/INT/NPT,NEL,NPUNCH,NSTOP,NJT,NPLOT,NKIND,NSEL,NGRCW,NGCOL,
     1NGSLCE
      CCMMON/MESH1/ NSCON(125,13), MF(125,8), ME(125,8), MFB(125,4),
     1MBA(125,4),  MEL(125,4),  NELB(125),  NELP(125)
      CCMMON/MESH2/ NRR(5,5),NCR(5,5),NSR(5),NELGS(5)
      CCMMON/MESH3/ NCON(200,21)
      CATA  MAXNEL/200/,MAXNJT/1296/
C
C        MAX. NO. ELEMENTS (MAXNEL) ANC MAX. NC. JCINTS (MAXNJT),
C        DETERMINED IN 'TRISOP'.
C
C        MESH2 CCMMCN ENTRY DIMENSIONEC (NGSLCE,NGCCL) CR (NGSLCE).
C
C        MESH3 COMMON ENTRY CIMENSIONEC (I,21) WHERE I=MAXNEL.
C
C        MESH2 AND MESH3 ALSC CONTAINEC IN SUBRCUTINES CCCRD AND GRID.
C
 10   FORMAT (///,' CONNECTIVITY MATRIX',//,4X,'EL',110X,'TYPE',//)
 11   FCRMAT (10I5,/,11I5)
 12   FCRMAT (I6,4X,20I5,4X,I4)
 13   FORMAT (//,' NUMBER OF ELEMENTS=',I4,//,' NUMBER CF JOINTS=',I4)
C
C        ZERO CCNNECTIVITY MATRIX
C
      CC 30 I=1,MAXNEL
      CC 25 J=1,21
 25   NCON(I,J)=C
```

```
 30     CCNTINUE
C
C       NUMBER OF ROWS AND COLUMNS IN EACH GRIC COLUMN
C             AND SUPER ELEMENT CONNECTIVITY
C
        K=1
        L1=NGROW-1
        DC 110 I=1,NGSLCE
        NSR(I)=0
        DC 110 J=1,NGCOL
        NRR(I,J)=0
        NCR(I,J)=0
        DC 100 L=1,NGROW
        IF (((I.EQ.NGSLCE).AND.(J.EQ.NGCOL)).AND.(L.EQ.L1)) GO TO 100
        IF (NSCCN(K,1).EQ.0) GC TO 100
        NRR(I,J)=NRR(I,J)+NSCON(K,1)
        NCR(I,J)=NSCON(K,2)
        NSR(I)=NSCCN(K,3)
        K1=K+1
        K2=K+NGRCW
        K3=K+NGRCW*NGCOL
        IF (NSCON(K, 5).NE.NSCON(K1, 4)) GO TO 35
        MF(K ,4)=1
        MF(K1,1)=1
 35     IF (NSCCN(K, 6).NE.NSCON(K1, 7)) GO TO 40
        MF(K ,5)=1
        MF(K1,8)=1
 40     IF (J.EQ.NGCOL) GO TO 50
        IF (NSCCN(K, 6).NE.NSCON(K2, 5)) GC TO 45
        MF(K ,6)=1
        MF(K2,3)=1
 45     IF (NSCCN(K, 7).NE.NSCON(K2, 4)) GC TO 50
        MF(K ,7)=1
        MF(K2,2)=1
 50     IF (NSCCN(K, 9).NE.NSCCN(K1, 8)) GC TO 55
        MB(K ,4)=1
        MB(K1,1)=1
 55     IF (NSCCN(K,10).NE.NSCCN(K1,11)) GC TO 60
        MB(K ,5)=1
        MB(K1,8)=1
 60     IF (J.EQ.NGCOL) GO TO 70
        IF (NSCCN(K,10).NE.NSCON(K2, 9)) GO TO 65
        MB(K ,6)=1
        MB(K2,3)=1
 65     IF (NSCCN(K,11).NE.NSCCN(K2, 8)) GO TO 70
        MB(K ,7)=1
        MB(K2,2)=1
 70     IF (I.EQ.NGSLCE) GC TO 100
```

```
      IF (NSCCN(K, 8).NE.NSCON(K3, 4)) GO TO 75
      MBA(K,1)=1
      MFB(K3,1)=1
 75   IF (NSCCN(K, 9).NE.NSCON(K3, 5)) GC TO 80
      MBA(K,2)=1
      MFB(K3,2)=1
 8C   IF (NSCCN(K,10).NE.NSCON(K3, 6)) GC TO 85
      MBA(K,3)=1
      MFB(K3,3)=1
 85   IF (NSCCN(K,11).NE.NSCON(K3, 7)) GO TO 100
      MBA(K,4)=1
      MFB(K3,4)=1
 10C  K=K+1
 110  CCNTINUE
C
C        ELEMENT CCNNECTIVITY
C
      NC1=1
      KK=1
      MM1=1
      KKS=1
      MMS1=1
      II=0
      III=0
      MCB=0
      NP1=1
      MPB=0
      NP2=0
      DC 900 IS=1,NGSLCE
      NELGS(IS)=0
      IIIB=IS-1
      LS1=NSR(IS)
      IF (LS1.EQ.0) GO TC 890
      III=III+1
      DC 800 LS=1,LS1
      LLS1=2
      LLS2=3
      IF (LS.EQ.LS1) LLS1=LLS2
      DC 700 LLS=1,LLS1
      NKIND=2
      IF ((LLS.NE.1).AND.(LLS.NE.LLS2)) NKIND=1
      L4=0
      IF ((LS.EQ.1).AND.(LLS.EQ.1)) L4=1
      DC 500 I=1,NGCOL
      L1=NCR(IS,I)
      IF (L1.EQ.0) GO TO 470
      II=II+1
      DC 450 L=1,L1
```

```
      LL1=NKIND
      LL2=NKIND+1
      IF (L.EG.L1) LL1=LL2
      DC 430 LL=1,LL1
      L3=0
      IF ((LL.EG.1).AND.(L.EQ.1)) L3=1
      NKIND1=NKIND
      IF ((LL.NE.1).AND.(LL.NE.LL2)) NKIND1=1
      K=KK
      M1=MM1
      DC 400 J=1,NGROW
      IF (NSCCN(K,1).EQ.0) GC TO 390
      KA=K-1
      KB=K+1
      KL=K-NGRCW
      KL1=KL-1
      KL2=KL+1
      KR=K+NGRCW
      KR1=KR-1
      KEK=K-NGRCW*NGCOL
      KLBK=KL-NGRCW*NGCOL
      DC 112 I7=1,4
      DC 112 I8=1,4
      MBK(I7,I8)=0
112   CCNTINUE
      DC 113 I7=1,4
      I8=I7+1
      IF (I7.EQ.4) I8=1
113   IF ((MFB(K,I7).EQ.1).AND.(MFB(K,I8).EQ.1)) MBK(I7,I8)=1
      GC TO (115,120,125),LLS
115   IF (LS.NE.1) GO TO 120
      DC 118 MF1=1,8
118   MS(MF1)=MF(K,MF1)
      GC TO 130
120   DC 123 MF1=1,8
      MS(MF1)=0
123   IF ((MF(K,MF1).EQ.1).AND.(MB(K,MF1).EQ.1)) MS(MF1)=1
      GC TO 130
125   DC 128 MF1=1,8
128   MS(MF1)=MB(K,MF1)
13C   IF (LL.NE.LL2) GO TC 145
      GC TO (131,132,133),LLS
131   IF (((MS(7).EQ.0).AND.(MS(8).EQ.1)).AND.(MF(KA,6).EQ.1)) NC1=NC1-1
      GC TO 134
132   IF ((((MS(7).EQ.0).AND.(MS(8).EQ.1)).AND.(MF(KA,6).EQ.1)).AND.
     1    (MB(KA,6).EQ.1)) NC1=NC1-1
      GC TO 134
133   IF (((MS(7).EQ.0).AND.(MS(8).EQ.1)).AND.(MB(KA,6).EQ.1)) NC1=NC1-1
```

```
 134   IF ((MS(6).EQ.1).AND.(MS(7).EQ.1)) GO TO 135
       GC TO 140
 135   IF (((III.NE.1).AND.(L4.EQ.1)).ANC.(MBK(3,4).EQ.1)) GO TO 145
       M1=M1+NSCON(K,1)
       GC TO 390
 140   IF (MS(7).EQ.1) NC1=NC1-1
 145   M2=M1+NSCON(K,1)-1
       IF (M2.GT.MAXNEL) GC TC 980
       DC 350 M=M1,M2
       MMIN1=M-1
       MMIN1K=MMIN1-NRR(IS,I)
       IF (LL.NE.1) GO TO 148
       IF (L.NE.1) GO TO 147
       IF (M.EG.M1) MEL(K,1)=M
       IF (M.EG.M2) MEL(K,2)=M
 147   IF (L.NE.L1) GO TC 148
       IF (M.EQ.M1) MEL(K,3)=M
       IF (M.EG.M2) MEL(K,4)=M
 148   GC TO (15C,2CO),NKIND
C
C          MID-SICE NODES
C
 15C   GC TO (160,185),LL
 160   NCCN(M,10)=NC1
       NCCN(M,11)=NC1+1
       IF (L.EQ.1) GO TO 165
       NCCN(MM2,9)=NCON(M,10)
       NCCN(MM2,12)=NCON(M,11)
       MM2=MM2+1
       GC TO 300
 165   IF(II.EG.1) GO TO 3C0
       IF ((MS(2).EQ.0).AND.(MS(3).EQ.0)) GO TO 3CC
       IF (M.NE.M1) GO TC 171
       MM3=MEL(KL,3)
       MM4=MEL(K,1)
 171   IF ((MS(2).EQ.1).AND.(MS(3).EQ.1)) GO TO 172
       GC TO 3CC
 172   NCCN(MM3,9)=NCON(MM4,10)
       NCCN(MM3,12)=NCON(MM4,11)
       MM3=MM3+1
       MM4=MM4+1
       GC TO 3C0
 185   NCCN(M,9)=NC1
       NCCN(M,12)=NC1+1
       GC TO 3C0
C
C          FRCNT AND BACK FACE NODES
C
```

```
200   DC 202 N=1,8
      NN=N
      IF (LLS.EC.LLS2) NN=N+12
202   NC(N)=NN
      N1=NC(1)
      N2=NC(2)
      N3=NC(3)
      N4=NC(4)
      N5=NC(5)
      N6=NC(6)
      N7=NC(7)
      N8=NC(8)
      GC TO (205,277,290),LL
205   IF (MCB.NE.1) GO TO 206
      IF (((MFB(K,1).EQ.1).OR.(MFB(K,2).EQ.1)).ANC.(L3.EQ.1)) GO TO 206
      IF (((MBK(4,1).EQ.1).CR.(MBK(2,3).EQ.1)).ANC.(L3.EC.0)) GO TC 206
      NCCN(M,3)=NCON(MMIN1,5)
      NC1=NC1-1
      GC TO 2C7
206   NCCN(M,N3)=NC1
207   NCCN(M,N4)=NC1+1
      NCCN(M,N5)=NC1+2
      MCB=0
      IF ((III.NE.1).AND.(L4.EQ.1)) GC TC 208
      GC TO 260
208   MBS4=MEL(KL2,3)
      IF (L.NE.1) GO TO 209
      IF ((((M.EQ.M2).AND.(MS(3).EQ.1)).AND.(MF(KL,5).EQ.1)).AND.
     1 (MFB(KL2,4).EQ.1)) NCCN(M,5)=NCCN(MBS4,1)
209   IF ((MFB(K,1).EQ.0).AND.(MFB(K,2).EQ.0)) GC TC 230
      IF (M.NE.M1) GO TO 210
      IF (L.EC.1) NELB(KBK)=MEL(KBK,1)
      MBS1=NELB(KBK)
210   IF (L.NE.1) GO TO 250
      IF (MBK(1,2).NE.1) GC TC 212
      NCCN(M,3)=NCON(MBS1,15)
      NCCN(M,4)=NCCN(MBS1,16)
      NCCN(M,5)=NCCN(MBS1,17)
      NC1=NC1-2
      IF ((MS(4).EQ.1).ANC.(M.EQ.M2)) MCB=1
      IF ((MS(4).EG.0).ANC.(M.EQ.M2)) NC1=NC1-1
      GC TO 216
212   IF (MFB(K,1).NE.1) GC TC 214
      IF (M.NE.M1) GO TO 216
      NCCN(M,3)=NCON(MBS1,15)
      NCCN(M,4)=NC1
      NCCN(M,5)=NC1+1
      NC1=NC1-1
```

```
      GO TO 216
214   IF (M.NE.M2) GO TO 218
      NCON(M,5)=NCON(MBS1,17)
      IF (MS(4).EQ.0) NC1=NC1-1
      IF (MS(4).EQ.1) MCB=1
      GO TO 218
216   IF (M.NE.M1) GO TO 218
      IF (MF(K,1).EQ.1) NCON(MMIN1,5)=NCON(M,3)
218   MBS1=MBS1+1
230   IF (L.NE.1) GO TO 260
      MBS6=MEL(KLBK,3)
      IF (M.EQ.M1) MBS3=MEL(KL,3)
      IF ((II.NE.1).AND.(M.EQ.M2)) MBS5=MEL(KLBK,4)
      IF ((MS(2).EQ.0).AND.(MS(3).EQ.0)) GO TO 260
      IF ((MFB(KL,3).EQ.0).AND.(MFB(KL,4).EQ.0)) GO TO 260
      IF ((MFB(K,1).EQ.1).OR.(MFB(K,2).EQ.1)) GO TO 260
      IF ((MFB(KL,3).EQ.1).AND.(MFB(KL,4).EQ.1)) GO TO 232
      GO TO 236
232   IF ((MS(2).EQ.1).AND.(MS(3).EQ.1)) GO TO 234
      GO TO 236
234   NCON(M,3)=NCON(MBS3,1)
      NCON(M,4)=NCON(MBS3,8)
      NCON(M,5)=NCON(MBS3,7)
      NC1=NC1-2
      IF ((MS(4).EQ.1).AND.(M.EQ.M2)) MCB=1
      IF ((MS(4).EQ.0).AND.(M.EQ.M2)) NC1=NC1-1
      GO TO 243
236   IF (((M.EQ.M1).AND.(MS(2).EQ.1)).AND.(MFB(KL,4).EQ.1)) GO TO 238
      GO TO 240
238   NCON(MBS3,1)=NCON(MBS6,13)
      NCON(M,3)=NCON(MBS3,1)
      NCON(M,4)=NC1
      NCON(M,5)=NC1+1
      NC1=NC1-1
      GO TO 243
240   IF (((M.EQ.M2).AND.(MS(3).EQ.1)).AND.(MFB(KL,3).EQ.1)) GO TO 241
      GO TO 243
241   NCON(MBS3,7)=NCON(MBS5,19)
      NCON(M,5)=NCON(MBS3,7)
242   IF (M.NE.M2) GO TO 244
      IF (MS(4).EQ.0) NC1=NC1-1
      IF (MS(4).EQ.1) MCB=1
      GO TO 244
243   IF (M.NE.M1) GO TO 244
      IF (MF(K,1).EQ.1) NCON(MMIN1,5)=NCON(M,3)
244   MBS3=MBS3+1
      GO TO 260
250   IF ((MBK(4,1).EQ.1).AND.(MBK(2,3).EQ.1)) GO TO 251
```

```
      GO TO 252
251   NCON(M,3)=NCON(MBS1,15)
      NCON(M,4)=NCON(MBS1,16)
      NCON(M,5)=NCON(MBS1,17)
      NC1=NC1-2
      IF (((MS(4).EQ.1).AND.(MS(5).EQ.1)).AND.(M.EQ.M2)) MCB=1
      IF ((MS(4).EQ.0).AND.(M.EQ.M2)) NC1=NC1-1
      GO TO 256
252   IF (MBK(4,1).NE.1) GO TO 254
      IF (M.NE.M1) GO TO 256
      NCON(M,3)=NCON(MBS1,15)
      NCON(M,4)=NC1
      NCON(M,5)=NC1+1
      NC1=NC1-1
      GO TO 256
254   IF (MBK(2,3).NE.1) GO TO 258
      IF (M.NE.M2) GO TO 258
      NCON(M,5)=NCON(MBS1,17)
      IF (MS(4).EQ.0) NC1=NC1-1
      IF ((MS(4).EQ.1).AND.(MS(5).EQ.1)) MCB=1
      GO TO 258
256   IF (M.NE.M1) GO TO 258
      IF ((MF(K,1).EQ.1).AND.(MF(K,8).EQ.1)) GO TO 257
      GO TO 258
257   NCON(MMIN1,5)=NCON(M,3)
      NCON(MMIN1K,7)=NCON(M,3)
258   MBS1=MBS1+1
260   IF (L.EQ.1) GO TO 265
      NCON(MM2,N1)=NCON(M,N3)
      NCON(MM2,N8)=NCON(M,N4)
      NCON(MM2,N7)=NCON(M,N5)
      MM2=MM2+1
      GO TO 300
265   IF(II.EQ.1) GO TO 300
      IF ((MS(2).EQ.0).AND.(MS(3).EQ.0)) GO TO 300
      IF (M.NE.M1) GO TO 270
      MM3=MEL(KL,3)
      MM4=MEL(K,1)
270   IF ((MS(2).EQ.1).AND.(MS(3).EQ.1)) GO TO 275
      GO TO 300
275   NCON(MM3,N1)=NCON(MM4,N3)
      NCON(MM3,N8)=NCON(MM4,N4)
      NCON(MM3,N7)=NCON(MM4,N5)
      MM3=MM3+1
      MM4=MM4+1
      GO TO 300
277   IF (MCB.NE.1) GO TO 278
      IF ((MBK(4,1).EQ.1).OR.(MBK(2,3).EQ.1)) GO TO 278
```

```
      NCON(M,2)=NCON(MMIN1,6)
      NC1=NC1-1
      GC TO 280
278   NCCN(M,N2)=NC1
28C   NCCN(M,N6)=NC1+1
      MCB=0
      IF ((III.NE.1).AND.(L4.EQ.1)) GO TO 281
      GC TO 3CO
281   IF (M.EG.M1) MBS1=NELB(KBK)
      IF ((MBK(4,1).EQ.1).AND.(MBK(2,3).EQ.1)) GO TC 282
      GC TO 283
282   NCCN(M,2)=NCON(MBS1,14)
      NCCN(M,6)=NCON(MBS1,18)
      NC1=NC1-1
      IF (((MS(4).EQ.1).AND.(MS(5).EQ.1)).AND.(M.EQ.M2)) MCB=1
      IF (((MS(4).EG.0).CR.(MS(5).EQ.0)).AND.(M.EG.M2)) NC1=NC1-1
      GC TO 285
283   IF (MBK(4,1).NE.1) GO TO 284
      IF (M.NE.M1) GO TC 284
      NCCN(M,2)=NCON(MBS1,14)
      NCCN(M,6)=NC1
      NC1=NC1-1
      GC TO 285
284   IF (MBK(2,3).NE.1) GO TC 286
      IF (M.NE.M2) GO TC 286
      NCCN(M,6)=NCON(MBS1,18)
      IF ((MS(4).EQ.0).CR.(MS(5).EQ.0)) NC1=NC1-1
      IF ((MS(4).EQ.1).AND.(MS(5).EQ.1)) MCB=1
      GC TO 286
285   IF (((M.EQ.M1).AND.(MF(K,1).EQ.1)).AND.(MF(K,8).EQ.1))
     1  NCON(MMIN1,6)=NCCN(M,2)
286   MBS1=MBS1+1
      IF (M.EG.M2) NELB(KBK)=NELB(KBK)+NRR(IIIB,I)
      GC TO 3CO
29C   NCCN(M,N1)=NC1
      NCCN(M,N8)=NC1+1
      NCCN(M,N7)=NC1+2
      IF ((III.NE.1).AND.(L4.EQ.1)) GC TO 291
      GC TO 3CO
291   IF ((MFB(K,3).EQ.0).AND.(MFB(K,4).EQ.0)) GC TO 300
      IF (M.EG.M1) MBS1=MEL(KBK,3)
      IF (MBK(3,4).NE.1) GO TO 292
      NCCN(M,1)=NCCN(MBS1,13)
      NCCN(M,8)=NCON(MBS1,20)
      NCCN(M,7)=NCON(MBS1,19)
      NC1=NC1-2
      IF(((MS(5).EQ.0).AND.(M.EQ.M2)).AND.(MS(6).NE.1)) NC1=NC1-1
      IF (M.NE.M1) GO TC 294
```

```
      IF ((MS(7).EQ.1).AND.(MS(6).EQ.0)) NC1=NC1+1
      IF (((MS(7).EQ.0).AND.(MS(8).EQ.1)).AND.(MF(KA,6).EQ.1)) NC1=NC1+1
      GC TO 294
292   IF (MFB(K,4).NE.1) GO TO 293
      IF (M.NE.M1) GO TC 294
      NCCN(M,1)=NCON(MBS1,13)
      IF ((MS(7).EQ.1).AND.(MS(6).EQ.0)) NC1=NC1+1
      IF (((MS(7).EQ.0).AND.(MS(8).EQ.1)).AND.(MF(KA,6).EQ.1)) NC1=NC1+1
      NCCN(M,8)=NC1
      NCCN(M,7)=NC1+1
      NC1=NC1-1
      GC TO 294
293   IF (MFB(K,3).NE.1) GO TO 295
      IF (M.NE.M2) GO TO 295
      NCCN(M,7)=NCON(MBS1,19)
      IF (MS(5).EQ.0) NC1=NC1-1
      GC TO 295
294   IF (M.NE.M1) GO TO 295
      IF (MF(K,8).EQ.1) NCON(MMIN1,7)=NCCN(M,1)
295   MES1=MBS1+1
300   NC1=NC1+NKIND1
      NCCN(M,21)=NSCON(K,12)
350   CCNTINUE
      IF ((II.NE.1).AND.(L3.EQ.1)) GO TO 355
      GC TO 375
355   IF ((MS(2).EQ.0).AND.(MS(3).EQ.0)) GO TO 375
      MM5=MEL(K,2)
      MM6=MEL(KL,4)
      MM7=MEL(KL1,4)
      MM8=MEL(KL2,3)
      MM9=MEL(KL,3)
      MM10=MEL(K,1)
      GC TO (360,365),NKIND
360   IF (MS(2).NE.1) GO TO 362
      NCCN(MM9,9)=NCON(MM10,10)
      IF ((MF(KL,8).EQ.1).AND.(MB(KL,8).EQ.1)) NCCN(MM7,12)=NCON(MM9,9)
362   IF (MS(3).NE.1) GO TO 375
      NCCN(MM6,12)=NCON(MM5,11)
      IF ((MF(KL,5).EQ.1).AND.(MB(KL,5).EQ.1)) NCCN(MM8,9)=NCCN(MM6,12)
      GC TC 375
365   IF (MS(2).NE.1) GC TO 367
      NCCN(MM9,N1)=NCON(MM10,N3)
      IF (MF(KL,8).EQ.1) NCCN(MM7,N7)=NCON(MM9,N1)
367   IF (MS(3).NE.1) GO TO 375
      NCCN(MM6,N7)=NCON(MM5,N5)
      IF (MF(KL,5).EQ.1) NCON(MM8,N1)=NCCN(MM6,N7)
375   IF ((  MS(4).EQ.0).AND.(L3.EQ.1)) NC1=NC1+1
      IF (((( MS(4).EQ.C).OR.(  MS(5).EQ.0)).ANC.(L3.EQ.0))
```

```
     1.AND.(LL.NE.LL2)) NC1=NC1+1
      IF (((   MS(5).EQ.0).AND.(   MS(6).NE.1)).AND.(LL.EQ.LL2)) NC1=NC1+1
380   M1=M2+1
390   K=K+1
400   CONTINUE
430   CONTINUE
      MM2=MM1
      MM1=M1
450   CONTINUE
      KK=K
      GO TO 500
470   KK=KK+NGROW
500   CONTINUE
      KK=KKS
      II=0
      IF ((LLS.EQ.1).AND.(LS.NE.1)) GO TO 505
      GO TO 530
505   DO 520 M=MMS1,M2
      DO 510 IC=1,8
      IC1=IC+12
510   NCON(MMS2,IC1)=NCON(M,IC)
520   MMS2=MMS2+1
530   IF (LLS.NE.LLS1) MM1=MMS1
700   CONTINUE
      MMS2=MMS1
      MMS1=M1
      NP1B=NP1-1
      IF (NP1.NE.1) MPB=NELP(NP1B)
      NP2=NP2+MPB
      NELP(NP1)=M-NP2
      NELGS(IS)=NELGS(IS)+NELP(NP1)
      NP1=NP1+1
800   CONTINUE
890   KKS=KKS+NGROW*NGCOL
      KK=KKS
900   CONTINUE
      NEL=M
      NJT=NCON(NEL,19)
      WRITE (6,13) NEL,NJT
      IF (NJT.GT.MAXNJT) GO TO 990
      WRITE (6,10)
      NBAND=0
      DO 950 I=1,NEL
      MAXB=0
      MINB=MAXNJT+1
      DO 910 J=1,8
910   IF (NCON(I,J).LT.MINB) MINB=NCON(I,J)
      DO 920 K=13,20
```

```
920   IF (NCON(I,K).GT.MAXB) MAXB=NCON(I,K)
      NBAND1=MAXB-MINB
      IF (NBAND1.GT.NBAND) NBAND=NBAND1
      IF(NPUNCH.EQ.0) GC TO 950
      WRITE (7,11) (NCCN(I,IN),IN=1,21)
950   WRITE (6,12) I,(NCON(I,IN),IN=1,21)
      NBAND=(NBAND+1)*3
      WRITE (6,975) NBAND
975   FCRMAT (///,' HALF BAND WIDTH FCR TRISOP STIFFNESS MATRIX=',I5)
      RETURN
98C   NSTCP=1
      WRITE (6,985) MAXNEL
985   FCRMAT (///,' DATA REJECTED***NUMBER OF ELEMENTS GREATER THAN',I5
     1,/,' ***********************************************************')
      RETURN
99C   NSTCP=1
      WRITE (6,995) MAXNJT
995   FCRMAT (///,' DATA REJECTED***NUMBER OF JCINTS GREATER THAN',I5
     1,/,' ***********************************************************')
      RETURN
      ENC



      SUBROUTINE COORD
C
C        THIS SUBROUTINE CETERMINES X,Y&Z COORDINATES OF JOINTS.
C        OUTPUT IS PRINTED WITH AN OPTICN TO PUNCH IN FORMAT
C        COMPATIBLE WITH 'TRISOP'.
C
      IMPLICIT REAL*8 (A-H,O-Z)
      IMPLICIT INTEGER*2 (I-N)
      CIMENSICN ND1(8),ND2(4),ND3(8),ND4(8),ND5(4),ND6(8),ND7(8),ND8(4),
     1ND9(8)
      DIMENSICN XI(20),ETA(20),ZETA(20)
      CCMMON/INT/NPT,NEL,NPUNCH,NSTOP,NJT,NPLOT,NKIND,NSEL,NGROW,NGCOL,
     1NGSLCE
      CCMMON/MESH1/ NSCON(125,13), MF(125,8), MB(125,8), MFB(125,4),
     1MBA(125,4),  MEL(125,4),  NELB(125),  NELP(125)
      CCMMON/MESH2/ NRR(5,5),NCR(5,5),NSR(5),NELGS(5)
      CCMMON/MESH3/ NCON(200,21)
      CCMMCN/CORD1/CORD(1296,3)
      CCMMCN/CORD2/BOUND(200,3)
      CCMMON/SF/ VAL(32)
      DATA ND1/3,4,5,10,11,15,16,17/
      DATA ND2/2,6,14,18/
```

```
      DATA ND3/1,8,7,9,12,13,20,19/
      DATA ND4/1,2,3,9,10,13,14,15/
      DATA ND5/4,8,16,20/
      DATA ND6/7,6,5,12,11,19,18,17/
      DATA ND7/1,2,3,4,5,6,7,8/
      DATA ND8/9,10,11,12/
      DATA ND9/13,14,15,16,17,18,19,20/
 20   FCRMAT (///,' COORCINATES OF JCINTS',//,' JCINT NUMBER',8X,
     1'X COORDINATE',5X,'Y CCORDINATE',5X,'Z CCCRCINATE',//)
 30   FCRMAT (5X,I3,12X,G14.5,2(3X,G14.5))
 40   FCRMAT (6X,I10,3F15.5)
C
C
      LL=1
      J1=1
      K=1
C
C        GRID SLICE
C
      CC 900 L=1,NGSLCE
      IF (NSR(L).EQ.0) GC TO 890
      J2=J1+NSR(L)-1
C
C        GRID CCLUMN
C
      CC 800 NK=1,NGCOL
      IF (NCR(L,NK).EQ.0) GO TO 790
C
C        GRID RCW
C
      CC 700 M=1,NGROW
      IF (NSCCN(K,1).EQ.0) GO TO 700
      NPTb=NSCON(K,13)
      CELXI =2.DO/(2*NSCON(K,2))
      CELETA=2.DC/(2*NSCCN(K,1))
      CELZET=2.DC/(2*NSCCN(K,3))
      XIVAL =-1.DO
      ETAVAL=1.DO
      ZETVAL=1.DC
      N2=NSCON(K,2)
C
C        SUPER ELEMENT SLICE
C
      CC 600 J=J1,J2
      IF (J.NE.J1) GO TO 5C
      NK1=MEL(K,1)-NELGS(L)+NELP(J)
      I1=NK1
C
```

```
C           SUPER ELEMENT CCLUMNS
C
 50     DC 500 N=1,N2
        I2=I1+NSCON(K,1)-1
C
C           SUPER ELEMENT RCWS
C
        DC 400 I=I1,I2
        DC 100 MM=1,8
        L1=ND1(MM)
 1C0    XI(L1)=XIVAL
        DC 120 MM=1,4
        L1=ND2(MM)
 120    XI(L1)=XIVAL+DELXI
        DC 140 MM=1,8
        L1=ND3(MM)
 140    XI(L1)=XIVAL+2*DELXI
        DC 160 MM=1,8
        L1=ND4(MM)
 16C    ETA(L1)=ETAVAL
        DC 180 MM=1,4
        L1=ND5(MM)
 18C    ETA(L1)=ETAVAL-DELETA
        DC 200 MM=1,8
        L1=ND6(MM)
 20C    ETA(L1)=ETAVAL-2*DELETA
        DC 220 MM=1,8
        L1=ND7(MM)
 22C    ZETA(L1)=ZETVAL
        DC 240 MM=1,4
        L1=ND8(MM)
 24C    ZETA(L1)=ZETVAL-DELZET
        DC 260 MM=1,8
        L1=ND9(MM)
 26C    ZETA(L1)=ZETVAL-2*DELZET
        DC 350 MM=1,20
        L2=NCON(I,MM)
        XI1=XI(MM)
        ETA1=ETA(MM)
        ZETA1=ZETA(MM)
        CALL SHAPE (XI1,ETA1,ZETA1,NPTB)
        CCRD(L2,1)=0.D0
        CCRD(L2,2)=0.D0
        CCRD(L2,3)=0.D0
        LLL=LL
        DC 300 NN=1,NPTB
        CCRD(L2,1)=CORD(L2,1)+VAL(NN)*BOUND(LLL,1)
        CCRD(L2,2)=CORD(L2,2)+VAL(NN)*BOUND(LLL,2)
```

```
      CCRD(L2,3)=CORD(L2,3)+VAL(NN)*BOUND(LLL,3)
30C    LLL=LLL+1
350   CCNTINUE
      ETAVAL=ETAVAL-2*DELETA
40C   CCNTINUE
      ETAVAL=1.DO
      I1=I1+NRR(L,NK)
      XIVAL=XIVAL+2*DELXI
50C   CCNTINUE
      XIVAL=-1.DO
      NK1=NK1+NELP(J)
      I1=NK1
      ZETVAL=ZETVAL-2*DELZET
600   CCNTINUE
      ZETVAL=1.DO
      LL=LL+NPTB
700   K=K+1
      GC TO 800
79C   K=K+NGRCW
80C   CCNTINUE
      J1=J2+1
      GC TO 900
890   K=K+NGRCW*NGCOL
90C   CCNTINUE
      WRITE (6,20)
      CC 950 I=1,NJT
      IF (NPUNCH.EQ.0) GC TO 950
      WRITE (7,40) I,(CORD(I,J),J=1,3)
950   WRITE (6,3C) I,(CORD(I,J),J=1,3)
      RETURN
      END
```

```
      SUBROUTINE SHAPE (X,Y,Z,NBNCDE)
      IMPLICIT REAL*8 (A-H,O-Z)
      IMPLICIT INTEGER*2 (I-N)
      DIMENSION XYZL(8,3),XYZQ(20,3),XYZC(32,3),IPERM(16)
      COMMON/SF/VAL(32)
      DATA XYZL/1.0D0,-1.0D0,-1.0D0,1.0D0,1.0D0,-1.0D0,-1.0D0,1.0D0,
     11.0D0,1.0D0,-1.0D0,-1.0D0,1.0D0,1.0D0,-1.0D0,-1.0D0,1.0D0,1.0D0,
     21.0D0,1.0D0,-1.0D0,-1.0D0,-1.0D0,-1.0D0/
      DATA XYZQ/1.0D0,0.0D0,-1.0D0,-1.0D0,-1.0D0,0.0D0,1.0D0,1.0D0,
     11.0D0,-1.0D0,-1.0D0,1.0D0,1.0D0,0.0D0,-1.0D0,-1.0D0,-1.0D0,0.0D0,
     21.0D0,1.0D0,1.0D0,1.0D0,1.0D0,0.0D0,-1.0D0,-1.0D0,-1.0D0,0.0D0,
     31.0D0,1.0D0,-1.0D0,-1.0D0,1.0D0,1.0D0,1.0D0,0.0D0,-1.0D0,-1.0D0,
     4-1.0D0,0.0D0,1.0D0,1.0D0,1.0D0,1.0D0,1.0D0,1.0D0,1.0D0,1.0D0,
     50.0D0,0.0D0,0.0D0,0.0D0,-1.0D0,-1.0D0,-1.0D0,-1.0D0,-1.0D0,-1.0D0,
     6-1.0D0,-1.0D0/
      DATA XYZC/1.0D0,.3333333333333333D0,-.3333333333333333D0,-1.0D0,
     1-1.0D0,-1.0D0,-1.0D0,-.3333333333333333D0,.3333333333333333D0,
     21.0D0,1.0D0,1.0D0,1.0D0,-1.0D0,-1.0D0,1.0D0,1.0D0,-1.0D0,-1.0D0,
     31.0D0,1.0D0,.3333333333333333D0,-.3333333333333333D0,-1.0D0,-1.0D0,
     4-1.0D0,-1.0D0,-.3333333333333333D0,.3333333333333333D0,1.0D0,1.0D0,
     51.0D0,1.0D0,1.0D0,1.0D0,1.0D0,.3333333333333333D0,
     6-.3333333333333333D0,-1.0D0,-1.0D0,-1.0D0,-1.0D0,
     7-.3333333333333333D0,.3333333333333333D0,1.0D0,1.0D0,-1.0D0,-1.0D0,
     81.0D0,1.0D0,-1.0D0,-1.0D0,1.0D0,1.0D0,1.0D0,1.0D0,
     9.3333333333333333D0,-.3333333333333333D0,-1.0D0,-1.0D0,-1.0D0,
     A-1.0D0,-.3333333333333333D0,.3333333333333333D0,1.0D0,1.0D0,1.0D0,
     B1.0D0,1.0D0,1.0D0,1.0D0,1.0D0,1.0D0,1.0D0,1.0D0,1.0D0,
     C.3333333333333333D0,.3333333333333333D0,.3333333333333333D0,
     D.3333333333333333D0,-.3333333333333333D0,-.3333333333333333D0,
     E-.3333333333333333D0,-.3333333333333333D0,-1.0D0,-1.0D0,-1.0D0,
     F-1.0D0,-1.0D0,-1.0D0,-1.0D0,-1.0D0,-1.0D0,-1.0D0,-1.0D0,-1.0D0/
      DATA IPERM/2,3,8,9,22,23,28,29,5,6,11,12,25,26,31,32/
      FL (X,Y,Z,X1,Y1,Z1) = (1.0D0+X*X1)*(1.0D0+Y*Y1)*(1.0D0+Z*Z1)/.8D1
      FQC(X,Y,Z,X1,Y1,Z1) = (1.0D0+X*X1)*(1.0D0+Y*Y1)*(1.0D0+Z*Z1)*
     1(X*X1+Y*Y1+Z*Z1-.2D1)/.8D1
      FQM(X,Y,Z,   Y1,Z1) = (1.0D0-X*X )*(1.0D0+Y*Y1)*(1.0D0+Z*Z1)/.4D1
      FCC(X,Y,Z,X1,Y1,Z1) = (1.0D0+X*X1)*(1.0D0+Y*Y1)*(1.0D0+Z*Z1)*
     1(.9D1*(X*X+Y*Y+Z*Z)-1.9D1)/6.4D1
      FCM(X,Y,Z,X1,Y1,Z1) = (1.0D0-X*X)*(1.0D0+.9D1*X*X1)*(1.0D0+Y*Y1)*
     1(1.0D0+Z*Z1)*.9D1/6.4D1
      IF (NBNCDE.EQ.32) GO TO 500
      IF (NBNCDE.EQ.20) GO TO 200
C
C        LINEAR FUNCTIONS
C
      DO 100 I=1,8
      X1=XYZL(I,1)
      Y1=XYZL(I,2)
```

```
      Z1=XYZL(I,3)
  100 VAL(I)=FL(X,Y,Z,X1,Y1,Z1)
      RETURN
C
C        QUADRATIC FUNCTICNS
C
  200 DC 250 I=1,7,2
      J=I+12
      X1=XYZQ(I,1)
      Y1=XYZQ(I,2)
      Z1=XYZQ(I,3)
      X2=XYZQ(J,1)
      Y2=XYZQ(J,2)
      Z2=XYZQ(J,3)
      VAL(I)=FQC(X,Y,Z,X1,Y1,Z1)
  250 VAL(J)=FQC(X,Y,Z,X2,Y2,Z2)
      DC 300 I=2,6,4
      J=I+12
      Y1=XYZQ(I,2)
      Z1=XYZQ(I,3)
      Y2=XYZQ(J,2)
      Z2=XYZQ(J,3)
      VAL(I)=FQM(X,Y,Z,Y1,Z1)
  300 VAL(J)=FQM(X,Y,Z,Y2,Z2)
      DC 350 I=4,8,4
      J=I+12
      X1=XYZQ(I,1)
      Z1=XYZQ(I,3)
      X2=XYZQ(J,1)
      Z2=XYZQ(J,3)
      VAL(I)=FQM(Y,Z,X,Z1,X1)
  350 VAL(J)=FQM(Y,Z,X,Z2,X2)
      DC 400 I=9,12
      X1=XYZQ(I,1)
      Y1=XYZQ(I,2)
  400 VAL(I)=FQM(Z,X,Y,X1,Y1)
      RETURN
C
C        CUBIC FUNCTIONS
C
  500 DC 550 I=1,10,3
      J=I+20
      X1=XYZC(I,1)
      Y1=XYZC(I,2)
      Z1=XYZC(I,3)
      X2=XYZC(J,1)
      Y2=XYZC(J,2)
      Z2=XYZC(J,3)
```

```
      VAL(I)=FCC(X,Y,Z,X1,Y1,Z1)
550   VAL(J)=FCC(X,Y,Z,X2,Y2,Z2)
      DO 600 I=1,8
      II=IPERM(I)
      X1=XYZC(II,1)
      Y1=XYZC(II,2)
      Z1=XYZC(II,3)
600   VAL(II)=FCM(X,Y,Z,X1,Y1,Z1)
      DO 650 I=9,16
      II=IPERM(I)
      X1=XYZC(II,1)
      Y1=XYZC(II,2)
      Z1=XYZC(II,3)
650   VAL(II)=FCM(Y,Z,X,Y1,Z1,X1)
      DO 700 I=13,20
      X1=XYZC(I,1)
      Y1=XYZC(I,2)
      Z1=XYZC(I,3)
700   VAL(I)=FCM(Z,X,Y,Z1,X1,Y1)
      RETURN
      END


      SUBROUTINE TRFR(TETA,ALPHA,BETA)
      IMPLICIT REAL*8 (A-H,O-Z)
      IMPLICIT INTEGER*2 (I-N)
      COMMON/INT/NPT,NEL,NPUNCH,NSTOP,NJT,NPLOT,NKIND,NSEL,NGROW,NGCOL,
     1NGSLCE
      COMMON/CORD1/CORD(1296,3)
      DIMENSION TFORM(3,3),DUM(3)
      CTET=DCOS(TETA)
      STET=DSIN(TETA)
      CALP=DCOS(ALPHA)
      SALP=DSIN(ALPHA)
      CBET=DCOS(BETA)
      SBET=DSIN(BETA)
      TFORM(1,1)=CTET*CBET-SALP*STET*SBET
      TFORM(1,2)=STET*CBET+SALP*CTET*SBET
      TFORM(1,3)=-SBET*CALP
      TFORM(2,1)=-STET*CALP
      TFORM(2,2)=CALP*CTET
      TFORM(2,3)=SALP
      TFORM(3,1)=SBET*CTET+STET*SALP*CBET
      TFORM(3,2)=STET*SBET-SALP*CTET*CBET
      TFORM(3,3)=CALP*CBET
```

```
      DC 300 I=1,NJT
      CC 100 J=1,3
      CUM(J)=C.ODO
      CC 100 K=1,3
  100 DUM(J)=DUM(J)+TFORM(J,K)*CORD(I,K)
      CC 200 J=1,3
  2CC CCRD(I,J)=DUM(J)
  3OC CCNTINUE
      RETURN
      ENC




      SUBROUTINE GRID
      IMPLICIT REAL*8 (A-H,O-Z)
      IMPLICIT INTEGER*2 (I-N)
      INTEGER*4 N1,MC,ITYPE,IXUP,IYRT,MCXAX,MDYAX,IWIDE,IHIGH,IGRID,LAST
      INTEGER*4 NJJ
      REAL*4 X,Y,XSCALE,YSCALE
      REAL LABEL/4H    /
      DIMENSICN X(20),Y(20),ISIX(2,3)
      DIMENSICN NPQ(3),INCQ(3)
      CCMMON/TITL/TITLE(12)
      CCMMON/MESH3/ NCON(200,33)
      CCMMON/INT/NPT,NEL,NPUNCH,NSTOP,NJT,NPLCT,NKINC,NSEL,NGRCW,NGCOL,
     1NGSLCE
      CCMMCN/CCRD1/CORD(1296,3)
      CATA ISIX/1,2,2,3,3,1/
      CATA NPQ/1,9,13/
      DATA INCQ/2,1,2/
      CATA ITYPE/0/ ,IXUP/15/,IYRT/0/ ,MDXAX/2/ ,MDYAX/2/ ,IWIDE/9/ ,
     1IHIGH/15/ ,IGRID/0/
      NKIND=2
      NPT=20
      DC 180 II=1,3
      XMAX=-1.CD+20
      YMAX=-1.0C+20
      XMIN= 1.CD+20
      YMIN= 1.CD+20
      I1=ISIX(1,II)
      I2=ISIX(2,II)
      CC 20 I=1,NJT
      XMAX=DMAX1(XMAX,CCRD(I,I1))
      YMAX=DMAX1(YMAX,CORD(I,I2))
      XMIN=DMIN1(XMIN,CORD(I,I1))
   20 YMIN=DMIN1(YMIN,CCRD(I,I2))
```

```
      IF (XMIN.GE.0.D0) GO TO 40
      XMAX=XMAX-XMIN
      DO 30 I=1,NJT
 30   CORD(I,I1)=CORD(I,I1)-XMIN
 40   IF (YMIN.GE.0.D0) GO TO 60
      YMAX=YMAX-YMIN
      DO 50 I=1,NJT
 50   CORD(I,I2)=CORD(I,I2)-YMIN
   60 CONTINUE
 110  XSCALE=1.5D0*(YMAX/9.D0)
      YSCALE=1.5D0*(XMAX/15.D0)
      IF (XSCALE.GT.YSCALE) YSCALE=XSCALE
      IF (XSCALE.LT.YSCALE) XSCALE=YSCALE
      N1=(NPT+4)/3 + 1
      MC=1
      MSTOP=0
      DO 170 I=1,NEL
      IF (I.EQ.NEL) MSTOP=3
C
      JT=N1-1
      DO 120 J=1,JT
      J1=NCON(I,J)
      IF (J.EQ.1) J2=J1
      X(J)=CORD(J1,I2)
 120  Y(J)=-CORD(J1,I1)
      J=J+1
      X(J)=CORD(J2,I2)
      Y(J)=-CORD(J2,I1)
      CALL DRAW (N1,X ,Y ,MC,ITYPE,LABEL,TITLE,XSCALE,YSCALE,IXUP,IYRT,
     1MDXAX,MDYAX,IWIDE,IHIGH,IGRID,LAST)
      MC=2
      JL=2*JT-3
      JTT=JL+JT-1
      DO 130 J=JL,JTT
      J1=NCON(I,J)
      IF (J.EQ.JL) J2=J1
      M=J-JL+1
      X(M)=CORD(J1,I2)
 130  Y(M)=-CORD(J1,I1)
      M=M+1
      X(M)=CORD(J2,I2)
      Y(M)=-CORD(J2,I1)
      CALL DRAW (N1,X ,Y ,MC,ITYPE,LABEL,TITLE,XSCALE,YSCALE,IXUP,IYRT,
     1MDXAX,MDYAX,IWIDE,IHIGH,IGRID,LAST)
      DO 160 JJJ=1,4
      JJ1=NKIND+1
      DO 150 JJ=1,JJ1
      J1=NPQ(JJ)+INCQ(JJ)*(JJJ-1)
```

```
      IF((MSTOP.EQ.3).AND.(JJJ.EQ.4))   MC=3
      JX=NCON(I,J1)
      X(JJ)=CORD(JX,I2)
  150 Y(JJ)=-CORD(JX,I1)
      NJJ=JJ
      CALL DRAW(NJJ,X ,Y ,MC,ITYPE,LABEL,TITLE,XSCALE,YSCALE,IXUP,IYRT,
     1MCXAX,MCYAX,IWIDE,IHIGH,IGRID,LAST)
  160 CONTINUE
  170 CONTINUE
  180 CONTINUE
      RETURN
      END
```

APPENDIX H

COMPUTER LISTING (TRIMEG-3)

```
C                                         ************
C                                         * TRIMEG-3 *
C                                         ************
C
      IMPLICIT REAL*8 (A-H,O-Z)
      IMPLICIT INTEGER*2 (I-N)
      DIMENSION NCT(200)
      COMMON/TITL/TITLE(12)
      COMMON/INT/NPT,NEL,NPUNCH,NSTOP,NJT,NPLOT,NKIND,NSEL,NGROW,NGCOL,
     1NGSLCE
      COMMON/MESH1/ NSCON(125,13), MF(125,8), ME(125,8), MFB(125,4),
     1MEA(125,4),  MEL(125,4),  NELB(125),  NELP(125)
C
C
      COMMON/CORD1/CORD(1296,3)
      COMMON/CORD2/BOUND(200,3)
C
C
      DATA MAXBJT/200/
      NGROW=5
      NGCOL=5
      NGSLCE=5
C
C        NGROW, NGCOL AND NGSLCE ARE MAX NO. OF SUPER ELEMENT ROWS,
C        COLUMNS AND SLICES RESPECTIVELY.
C
C        MESH1 COMMON ENTRIES DIMENSIONED (I,*),
C        WHERE I=(NGROW+1)*NGCOL*(NGSLCE+1)
C
C        MESH1 ALSO CONTAINED IN SUBROUTINES CONN, COORD, AND GRID.
C
C        CORD1 COMMON ENTRIES DIMENSIONED MAX JOINTS IN "TRISOP".
C
C        CORD1 ALSO CONTAINED IN SUBROUTINES COORD AND GRID.
C
C        CORD2 COMMON ENTRY DIMENSIONED (I,3) AND NCT DIMENSIONED (I),
C        WHERE I=MAXBJT ABOVE. THIS IS ARBITRARY.
C
C        CORD2 ALSO CONTAINED IN SUBROUTINE COORD.
C
 5    READ (5,10,END=9000) (TITLE(I),I=1,6)
      READ (5,10) (TITLE(I),I=7,12)
      WRITE (6,20) (TITLE(I),I=1,6)
      WRITE (6,22) (TITLE(I),I=7,12)
      READ (5, 9) NSEL,NPUNCH,NPLOT,TETA,ALPHA,BETA
      WRITE (6,35)
      WRITE (6,33) NSEL,NPUNCH,NPLOT,TETA,ALPHA,BETA
 9    FORMAT (3I5,3F5.0)
```

```
 10   FORMAT (6A8)
 11   FORMAT (14I5)
 20   FORMAT ('1',6A8)
 22   FORMAT (1X,6A8)
 25   FORMAT (3I5,3F20.0)
 28   FORMAT (4X,I3,6X,I3,5X,I3,3(3X,G25.15))
 30   FORMAT (//,' BOUNDARY DATA',//,'   SEL NO.',2X,'NODE NO.',2X,
     1'NCT',9X,'X COORDINATE',16X,'Y COORDINATE',16X,'Z COORDINATE',//)
 31   FORMAT (10X,I3,8X,12(I3,3X),I3)
 33   FORMAT (10X,I3,3X,I3,6X,I3,4X,3F7.2)
 34   FORMAT (///,' SUPER ELEMENT DATA',//,9X,'SEL NO.',6X,'ROW',
     1'   COL   SLICE   (A)    (B)    (C)    (D)    (E)    (F)    (G)    (H)   TYP
     2E  NPTSB',/)
 35   FORMAT (///,' MESH PARAMETERS',//,10X,'NSEL   NPUNCH   NPLOT',4X,
     1  'TETA',3X,'ALPHA',3X,'BETA',/)
      PI=3.141592654D0
      TETA=TETA*PI/180.0D0
      ALPHA=ALPHA*PI/180.0D0
      BETA=BETA*PI/180.0D0
      NSTOP=0
      K=1
      DO 40 MM=1,NGSLCE
      DO 40 I=1,NGCOL
      DO 39 J=1,NGROW
      DO 36 L=1,13
 36   NSCON(K,L)=0
      DO 37 M=1,8
      MF(K,M)=0
      MB(K,M)=0
 37   MEL(K,M)=0
      DO 38 N=1,4
      MFB(K,N)=0
 38   MBA(K,N)=0
 39   K=K+1
 40   CONTINUE
C
C        SUPER ELEMENT DATA
C
      NPTSBT=0
      WRITE (6,34)
      DO 60 N=1,NSEL
      IF (NPTSBT.GT.MAXBJT) NSTOP=2
      READ (5,11)   I,(NSCON(I,J),J=1,13)
      WRITE (6,31)  I,(NSCON(I,J),J=1,13)
 60   NPTSBT=NPTSBT+NSCON(I,13)
C
C        BOUNDARY DATA
C
```

```
      WRITE (6,3C)
      NLIN=0
      NBS1=0
      CC 70 I=1,NPTSBT
      READ (5,25)   NBSEL,NBNODE,NCT(I),(BOUND(I,J),J=1,3)
      IF (NBSEL.LT.NBS1) NSTOP=1
      NBS1=NBSEL
      IF (NCT(I).GT.0) NLIN=1
   7C WRITE (6,28)  NBSEL,NBNODE,NCT(I),(BOUND(I,J),J=1,3)
      IF (NSTCP.EQ.1) GO TO 170
      IF (NSTCP.EQ.2) GC TC 180
C
C        STRAIGHT BOUNDARY MID-SIDE NODES
C
      IF (NLIN.EQ.0) GC TC 190
      K=1
      NSELT=NGCCL*NGROW*NGSLCE
      CC 160 J=1,NSELT
      IF (NSCCN(J,1).EQ.C) GO TO 160
      IF (NSCCN(J,13).EQ.  8) GO TO 155
      NPT1=NSCON(J,13)
      CC 150 I=1,NPT1
      IF (NSCCN(J,13).EQ.32) GO TO 120
      IF (NCT(K).NE.1) GC TO 150
      IF ((I.GE.9).AND.(I.LE.12)) GO TC 100
      M=K-1
      N=K+1
      IF ((I.EQ.8).OR.(I.EQ.20)) N=K-7
      GC TO 110
  100 I1=I-8
      GC TO (102,104,106,108),I1
  102 M=K-8
      N=K+4
      GC TO 110
  104 M=K-7
      N=K+5
      GC TO 110
  106 M=K-6
      N=K+6
      GC TO 110
  108 M=K-5
      N=K+7
  110 BCUND(K,1)=(BCUND(M,1)+BOUNC(N,1))/2.0D0
      BCUND(K,2)=(BCUND(M,2)+BOUNC(N,2))/2.0D0
      BCUND(K,3)=(BCUND(M,3)+BOUNC(N,3))/2.0D0
      GC TO 150
  120 IF (NCT(K).NE.2) GC TO 150
      IF ((I.GE.13).AND.(I.LE.20)) GO TC 130
```

```
      K1=K+1
      I1=I+1
      IF ((NCT(K1).NE. 2).CR.(I1.EQ.13)) GO TC 150
      M=K-1
      N=K+2
      IF ((I.EQ.11).OR.(I.EQ.31)) N=K-10
       GC TO 144
  130 K1=K+4
      I1=I+4
      IF (I1.GT.20) GO TC 150
      I2=I-12
      GC TO (137,139,141,143),I2
  137 M=K-12
      N=K+8
      GC TO 144
  139 M=K-10
      N=K+10
      GC TO 144
  141 M=K-8
      N=K+12
      GC TO 144
  143 M=K-6
      N=K+14
  144 BMIDX=BCUND(M,1)-BCUNC(N,1)
      BMIDY=BCUND(M,2)-BCUNC(N,2)
      BMIDZ=BCUNC(M,3)-BCUND(N,3)
      BCUND(K,1)=BOUND(M,1)-BMIDX/3.0DC
      BCUND(K,2)=BCUND(M,2)-BMIDY/3.0DO
      BCUND(K,3)=BOUND(M,3)-BMIDZ/3.0DO
      BCUND(K1,1)=BOUND(M,1)-2*BMIDX/3.0DO
      BCUND(K1,2)=BCUND(M,2)-2*BMIDY/3.0DO
      BCUND(K1,3)=BOUND(M,3)-2*BMIDZ/3.0DO
  150 K=K+1
      GC TO 160
  155 K=K+8
  160 CCNTINUE
C
C
      DC 165 I=1,NPTSBT
  165 WRITE (6,28)  NBSEL,NBNCDE,NCT(I),(BOUND(I,J),J=1,3)
C
C
      GC TO 190
  170 WRITE (6,175)
  175 FCRMAT (///,'  DATA REJECTED***SUPER ELEMENT NUMBERS NOT IN ASCEND
     1ING ORDER FCR BOUNCARY INPUT DATA.',/,
     2'****************************************************',///)
       GC TO 5
```

```
 180  WRITE (6,185) MAXBJT
 185  FORMAT (///,'  DATA REJECTED***NUMBER OF BCUNDARY NODES GREATER TH
     1AN',I5,/,'***************************************************',/)
      GC TO 5
 19C  NSTOP=0
      CALL CONN
      IF (NSTCP.EQ.1) GO TO 5
      CALL COCRD
      IF (NPLCT.NE.1) GC TO 5
      CALL TRFR(TETA,ALPHA,BETA)
      CALL GRID
      GC TO 5
9COC  STCP
      END



      SUBROUTINE CONN
C
C        THIS SUBROUTINE CETERMINES ELEMENT CONNECTIVITY. OUTPUT IS
C        PRINTED WITH OPTICN TO PUNCH IN FORMAT CCMPATIBLE WITH "TRISOP"
C
      IMPLICIT REAL*8 (A-H,O-Z)
      IMPLICIT INTEGER*2 (I-N)
      DIMENSICN MS(8),NC(20),MBK(4,4)
      COMMON/INT/NPT,NEL,NPUNCH,NSTOP,NJT,NPLOT,NKIND,NSEL,NGROW,NGCOL,
     1NGSLCE
      CCMMON/MESH1/ NSCON(125,13), MF(125,8), MB(125,8), MFB(125,4),
     1MBA(125,4),  MEL(125,4),  NELB(125),  NELP(125)
      CCMMON/MESH2/ NRR(5,5),NCR(5,5),NSR(5),NELGS(5)
      CCMMCN/MESH3/ NCCN(200,33)
      DATA  MAXNEL/200/,MAXNJT/1296/
C
C        MAX. NO. ELEMENTS (MAXNEL) ANC MAX. NC. JCINTS (MAXNJT),
C        DETERMINED IN 'TRISCP'.
C
C        MESH2 CCMMCN ENTRY DIMENSIONEC (NGSLCE,NGCCL) OR (NGSLCE).
C
C        MESH3 COMMCN ENTRY DIMENSIONEC (I,33) WHERE I=MAXNEL.
C
C        MESH2 AND MESH3 ALSC CONTAINEC IN SUBRCUTINES COORD AND GRID.
C
 10   FCRMAT (///,' CCNNECTIVITY MATRIX',//,4X,'EL',108X,'TYPE',//)
 11   FCRMAT (16I4,/,17I4)
 12   FCRMAT (I6,5X,16I6,/,14X,17I6,/)
 13   FCRMAT (//,' NUMBER CF ELEMENTS=',I4,//,' NUMBER CF JOINTS=',I4)
```

```
C
C        ZERO CCNNECTIVITY MATRIX
C
      DC 30 I=1,MAXNEL
      CC 25 J=1,33
 25   NCCN(I,J)=0
 30      CONTINUE
C
C        NUMBER CF ROWS ANC CCLUMNS IN EACH GRIC COLUMN
C              AND SUPER ELEMENT CONNECTIVITY
C
      K=1
      L1=NGROW-1
      CC 110 I=1,NGSLCE
      NSR(I)=0
      CC 110 J=1,NGCOL
      NRR(I,J)=0
      NCR(I,J)=0
      CC 100 L=1,NGROW
      IF (((I.EQ.NGSLCE).AND.(J.EQ.NGCOL)).AND.(L.EQ.L1)) GO TO 100
      IF (NSCCN(K,1).EC.C) GC TO 100
      NRR(I,J)=NRR(I,J)+NSCON(K,1)
      NCR(I,J)=NSCON(K,2)
      NSR(I)=NSCCN(K,3)
      K1=K+1
      K2=K+NGRCW
      K3=K+NGROW*NGCOL
      IF (NSCCN(K, 5).NE.NSCON(K1, 4)) GO TO 35
      MF(K ,4)=1
      MF(K1,1)=1
 35   IF (NSCCN(K, 6).NE.NSCCN(K1, 7)) GO TO 4C
      MF(K ,5)=1
      MF(K1,8)=1
 40   IF (J.EG.NGCOL) GC TO 50
      IF (NSCCN(K, 6).NE.NSCON(K2, 5)) GC TO 45
      MF(K ,6)=1
      MF(K2,3)=1
 45   IF (NSCON(K, 7).NE.NSCON(K2, 4)) GC TO 50
      MF(K ,7)=1
      MF(K2,2)=1
 50   IF (NSCCN(K, 9).NE.NSCON(K1, 8)) GC TO 55
      ME(K ,4)=1
      MB(K1,1)=1
 55   IF (NSCCN(K,10).NE.NSCON(K1,11)) GO TO 60
      MB(K ,5)=1
      MB(K1,8)=1
 60   IF (J.EG.NGCOL) GO TO 70
      IF (NSCCN(K,10).NE.NSCCN(K2, 9)) GC TO 65
```

```
      MB(K ,6)=1
      MB(K2,3)=1
 65   IF (NSCCN(K,11).NE.NSCON(K2, 8)) GO TO 70
      MB(K ,7)=1
      MB(K2,2)=1
 70   IF (I.EQ.NGSLCE) GC TO 100
      IF (NSCCN(K, 8).NE.NSCON(K3, 4)) GC TO 75
      MBA(K,1)=1
      MFB(K3,1)=1
 75   IF (NSCON(K, 9).NE.NSCON(K3, 5)) GC TO 80
      MBA(K,2)=1
      MFB(K3,2)=1
 80   IF (NSCCN(K,10).NE.NSCON(K3, 6)) GO TO 85
      MBA(K,3)=1
      MFB(K3,3)=1
 85   IF (NSCCN(K,11).NE.NSCON(K3, 7)) GO TO 10C
      MBA(K,4)=1
      MFB(K3,4)=1
 100  K=K+1
 11C  CCNTINUE
C
C        ELEMENT CCNNECTIVITY
C
      NC1=1
      KK=1
      MM1=1
      KKS=1
      MMS1=1
      II=C
      III=0
      MCB=0
      NP1=1
      MFB=0
      NP2=0
      DC 900 IS=1,NGSLCE
      NELGS(IS)=0
      IIIB=IS-1
      LS1=NSR(IS)
      IF (LS1.EQ.0) GO TC 890
      III=III+1
      DC 800 LS=1,LS1
      LLS1=3
      LLS2=4
      IF (LS.EQ.LS1) LLS1=LLS2
      DC 700 LLS=1,LLS1
      NKIND=3
      IF ((LLS.NE.1).AND.(LLS.NE.LLS2)) NKIND=1
      L4=0
```

```
      IF ((LS.EQ.1).AND.(LLS.EQ.1)) L4=1
      DO 500 I=1,NGCOL
      L1=NCR(IS,I)
      IF (L1.EQ.0) GO TO 470
      II=II+1
      DO 450 L=1,L1
      LL1=NKIND
      LL2=NKIND+1
      IF (L.EQ.L1) LL1=LL2
      DO 430 LL=1,LL1
      L3=0
      IF ((LL.EQ.1).AND.(L.EQ.1)) L3=1
      NKIND1=NKIND
      IF ((LL.NE.1).AND.(LL.NE.LL2)) NKIND1=1
      K=KK
      M1=MM1
      DO 400 J=1,NGROW
      IF (NSCON(K,1).EQ.0) GO TO 390
      KA=K-1
      KB=K+1
      KL=K-NGROW
      KL1=KL-1
      KL2=KL+1
      KR=K+NGROW
      KR1=KR-1
      KBK=K-NGROW*NGCOL
      KLBK=KL-NGROW*NGCOL
      DO 112 I7=1,4
      DO 112 I8=1,4
      MBK(I7,I8)=0
112   CONTINUE
      DO 113 I7=1,4
      I8=I7+1
      IF (I7.EQ.4) I8=1
113   IF ((MFB(K,I7).EQ.1).AND.(MFB(K,I8).EQ.1)) MBK(I7,I8)=1
      GO TO (115,120,120,125),LLS
115   IF (LS.NE.1) GO TO 120
      DO 118 MF1=1,8
118   MS(MF1)=MF(K,MF1)
      GO TO 130
120   DO 123 MF1=1,8
      MS(MF1)=0
123   IF ((MF(K,MF1).EQ.1).AND.(MB(K,MF1).EQ.1)) MS(MF1)=1
      GO TO 130
125   DO 128 MF1=1,8
128   MS(MF1)=MB(K,MF1)
130   IF (LL.NE.LL2) GO TO 145
      GO TO (131,132,132,133),LLS
```

```
  131   IF (((MS(7).EQ.0).AND.(MS(8).EQ.1)).AND.(MF(KA,6).EQ.1)) NC1=NC1-1
        GO TO 134
  132   IF ((((MS(7).EQ.0).AND.(MS(8).EQ.1)).AND.(MF(KA,6).EQ.1)).AND.
       1     (MB(KA,6).EQ.1)) NC1=NC1-1
        GO TO 134
  133   IF (((MS(7).EQ.0).AND.(MS(8).EQ.1)).AND.(MB(KA,6).EQ.1)) NC1=NC1-1
  134   IF ((MS(6).EQ.1).AND.(MS(7).EQ.1)) GO TO 135
        GO TO 140
  135   IF (((III.NE.1).AND.(L4.EQ.1)).AND.(MBK(3,4).EQ.1)) GO TO 145
        M1=M1+NSCON(K,1)
        GO TO 390
  140   IF (MS(7).EQ.1) NC1=NC1-1
  145   M2=M1+NSCON(K,1)-1
        IF (M2.GT.MAXNEL) GO TO 980
        DO 350 M=M1,M2
        MMIN1=M-1
        MMIN1K=MMIN1-NRR(IS,I)
        IF (LL.NE.1) GO TO 148
        IF (L.NE.1) GO TO 147
        IF (M.EQ.M1) MEL(K,1)=M
        IF (M.EQ.M2) MEL(K,2)=M
  147   IF (L.NE.L1) GO TO 148
        IF (M.EQ.M1) MEL(K,3)=M
        IF (M.EQ.M2) MEL(K,4)=M
  148   GO TO (150,200,200),NKIND
C
C          MID-SIDE NODES
C
  150   DO 155 N=13,16
        NN=N
        IF (LLS.EQ.3) NN=N+4
  155   NC(N)=NN
        N13=NC(13)
        N14=NC(14)
        N15=NC(15)
        N16=NC(16)
        GO TO (160,185),LL
  160   NCON(M,N14)=NC1
        NCON(M,N15)=NC1+1
        IF (L.EQ.1) GO TO 165
        NCON(MM2,N13)=NCON(M,N14)
        NCON(MM2,N16)=NCON(M,N15)
        MM2=MM2+1
        GO TO 300
  165   IF(II.EQ.1) GO TO 300
        IF ((MS(2).EQ.0).AND.(MS(3).EQ.0)) GO TO 300
        IF (M.NE.M1) GO TO 171
        MM3=MEL(KL,3)
```

```
      MM4=MEL(K,1)
 171  IF ((MS(2).EQ.1).AND.(MS(3).EQ.1)) GO TO 172
      GC TO 3CO
 172  NCCN(MM3,N13)=NCCN(MM4,N14)
      NCON(MM3,N16)=NCCN(MM4,N15)
      MM3=MM3+1
      MM4=MM4+1
      GC TO 3CO
 185  NCCN(M,N13)=NC1
      NCCN(M,N16)=NC1+1
      GC TO 3CO
C
C        FRONT AND BACK FACE NODES
C
 200  DC 202 N=1,12
      NN=N
      IF (LLS.EQ.LLS2) NN=N+20
 202  NC(N)=NN
      N1=NC(1)
      N2=NC(2)
      N3=NC(3)
      N4=NC(4)
      N5=NC(5)
      N6=NC(6)
      N7=NC(7)
      N8=NC(8)
      N 9=NC( 9)
      N1C=NC(10)
      N11=NC(11)
      N12=NC(12)
      GC TO (205,276,276,290),LL
 205  IF (MCB.NE.1) GO TO 206
      IF (((MFB(K,1).EQ.1).OR.(MFB(K,2).EQ.1)).ANC.(L3.EQ.1)) GO TO 206
      IF (((MBK(4,1).EQ.1).CR.(MBK(2,3).EQ.1)).ANC.(L3.EQ.0)) GO TC 206
      NCCN(M,4)=NCCN(MMIN1,7)
      NC1=NC1-1
      GC TO 207
 206  NCCN(M,N4)=NC1
 207  NCCN(M,N5)=NC1+1
      NCCN(M,N6)=NC1+2
      NCCN(M,N7)=NC1+3
      MCB=0
      IF ((III.NE.1).AND.(L4.EQ.1)) GC TO 208
      GC TO 260
 208  MBS4=MEL(KL2,3)
      IF (L.NE.1) GO TC 209
      IF ((((M.EQ.M2).AND.(MS(3).EQ.1)).AND.(MF(KL,5).EQ.1)).AND.
     1 (MFB(KL2,4).EQ.1)) NCON(M,7)=NCCN(MBS4,1)
```

```
209   IF ((MFB(K,1).EQ.0).AND.(MFB(K,2).EQ.0)) GO TO 230
      IF (M.NE.M1) GO TO 210
      IF (L.EQ.1) NELB(KBK)=MEL(KBK,1)
      MBS1=NELB(KBK)
210   IF (L.NE.1) GO TO 250
      IF (MBK(1,2).NE.1) GO TO 212
      NCON(M,4)=NCON(MBS1,24)
      NCON(M,5)=NCON(MBS1,25)
      NCON(M,6)=NCON(MBS1,26)
      NCON(M,7)=NCON(MBS1,27)
      NC1=NC1-3
      IF ((MS(4).EQ.1).AND.(M.EQ.M2)) MCB=1
      IF ((MS(4).EQ.0).AND.(M.EQ.M2)) NC1=NC1-1
      GO TO 216
212   IF (MFB(K,1).NE.1) GO TO 214
      IF (M.NE.M1) GO TO 216
      NCON(M,4)=NCON(MBS1,24)
      NCON(M,5)=NC1
      NCON(M,6)=NC1+1
      NCON(M,7)=NC1+2
      NC1=NC1-1
      GO TO 216
214   IF (M.NE.M2) GO TO 218
      NCON(M,7)=NCON(MBS1,27)
      IF (MS(4).EQ.0) NC1=NC1-1
      IF (MS(4).EQ.1) MCB=1
      GO TO 218
216   IF (M.NE.M1) GO TO 218
      IF (MF(K,1).EQ.1) NCON(MMIN1,7)=NCON(M,4)
218   MBS1=MBS1+1
230   IF (L.NE.1) GO TO 260
      MBS6=MEL(KLBK,3)
      IF (M.EQ.M1) MBS3=MEL(KL,3)
      IF ((II.NE.1).AND.(M.EQ.M2)) MBS5=MEL(KLBK,4)
      IF ((MS(2).EQ.0).AND.(MS(3).EQ.0)) GO TO 260
      IF ((MFB(KL,3).EQ.0).AND.(MFB(KL,4).EQ.0)) GO TO 260
      IF ((MFB(K,1).EQ.1).OR.(MFB(K,2).EQ.1)) GO TO 260
      IF ((MFB(KL,3).EQ.1).AND.(MFB(KL,4).EQ.1)) GO TO 232
      GO TO 236
232   IF ((MS(2).EQ.1).AND.(MS(3).EQ.1)) GO TO 234
      GO TO 236
234   NCON(M,4)=NCON(MBS3,1)
      NCON(M,5)=NCON(MBS3,12)
      NCON(M,6)=NCON(MBS3,11)
      NCON(M,7)=NCON(MBS3,10)
      NC1=NC1-3
      IF ((MS(4).EQ.1).AND.(M.EQ.M2)) MCB=1
      IF ((MS(4).EQ.0).AND.(M.EQ.M2)) NC1=NC1-1
```

```
      GC TO 243
236   IF (((M.EQ.M1).AND.(MS(2).EQ.1)).AND.(MFB(KL,4).EQ.1)) GO TO 238
      GC TO 240
238   NCCN(MBS3,1)=NCON(MBS6,21)
      NCCN(M,4)=NCON(MBS3,1)
      NCCN(M,5)=NC1
      NCCN(M,6)=NC1+1
      NCCN(M,7)=NC1+2
      NC1=NC1-1
      GC TO 243
240   IF (((M.EQ.M2).AND.(MS(3).EQ.1)).AND.(MFB(KL,3).EQ.1)) GO TO 241
      GC TC 243
241   NCCN(MBS3,10)=NCON(MBS5,30)
      NCCN(M,7)=NCON(MBS3,10)
242   IF (M.NE.M2) GO TO 244
      IF (MS(4).EQ.0) NC1=NC1-1
      IF (MS(4).EQ.1) MCB=1
      GC TO 244
243   IF (M.NE.M1) GO TO 244
      IF (MF(K,1).EQ.1) NCON(MMIN1,7)=NCON(M,4)
244   MBS3=MBS3+1
      GC TO 260
250   IF ((MBK(4,1).EQ.1).ANC.(MBK(2,3).EQ.1)) GC TO 251
      GC TO 252
251   NCCN(M,4)=NCCN(MBS1,24)
      NCCN(M,5)=NCON(MBS1,25)
      NCCN(M,6)=NCON(MBS1,26)
      NCCN(M,7)=NCCN(MBS1,27)
      NC1=NC1-3
      IF (((MS(4).EQ.1).AND.(MS(5).EQ.1)).AND.(M.EQ.M2)) MCB=1
      IF ((MS(4).EQ.0).ANC.(M.EQ.M2)) NC1=NC1-1
      GC TO 256
252   IF (MBK(4,1).NE.1) GO TO 254
      IF (M.NE.M1) GO TC 256
      NCCN(M,4)=NCCN(MBS1,24)
      NCCN(M,5)=NC1
      NCCN(M,6)=NC1+1
      NCCN(M,7)=NC1+2
      NC1=NC1-1
      GC TO 256
254   IF (MBK(2,3).NE.1) GO TO 258
      IF (M.NE.M2) GO TC 258
      NCCN(M,7)=NCON(MBS1,27)
      IF (MS(4).EQ.0) NC1=NC1-1
      IF ((MS(4).EQ.1).AND.(MS(5).EQ.1)) MCB=1
      GC TO 258
256   IF (M.NE.M1) GO TC 258
      IF ((MF(K,1).EQ.1).AND.(MF(K,8).EQ.1)) GC TC 257
```

```
      GO TO 258
257   NCON(MMIN1,7)=NCON(M,4)
      NCON(MMIN1K,10)=NCON(M,4)
258   MBS1=MBS1+1
260   IF (L.EQ.1) GO TO 265
      NCON(MM2,N1)=NCON(M,N4)
      NCON(MM2,N12)=NCON(M,N5)
      NCON(MM2,N11)=NCON(M,N6)
      NCON(MM2,N10)=NCON(M,N7)
      MM2=MM2+1
      GO TO 300
265   IF(II.EQ.1) GO TO 300
      IF ((MS(2).EQ.0).AND.(MS(3).EQ.0)) GO TO 300
      IF (M.NE.M1) GO TO 270
      MM3=MEL(KL,3)
      MM4=MEL(K,1)
270   IF ((MS(2).EQ.1).AND.(MS(3).EQ.1)) GO TO 275
      GO TO 300
275   NCON(MM3,N1)=NCON(MM4,N4)
      NCON(MM3,N12)=NCON(MM4,N5)
      NCON(MM3,N11)=NCON(MM4,N6)
      NCON(MM3,N10)=NCON(MM4,N7)
      MM3=MM3+1
      MM4=MM4+1
      GO TO 300
276   N23=23
      N28=28
      IF (LL.NE.3) GO TO 277
      N3=N2
      N8=N9
      N23=22
      N28=29
277   IF (MCB.NE.1) GO TO 279
      IF ((MBK(4,1).EQ.1).OR.(MBK(2,3).EQ.1)) GO TO 279
      NCON(M,N3)=NCON(MMIN1,N8)
      NC1=NC1-1
      GO TO 280
279   NCON(M,N3)=NC1
280   NCON(M,N8)=NC1+1
      MCB=0
      IF ((III.NE.1).AND.(L4.EQ.1)) GO TO 281
      GO TO 300
281   IF (M.EQ.M1) MBS1=NELB(KBK)
      IF ((MBK(4,1).EQ.1).AND.(MBK(2,3).EQ.1)) GO TO 282
      GO TO 283
282   NCON(M,N3)=NCON(MBS1,N23)
      NCON(M,N8)=NCON(MBS1,N28)
      NC1=NC1-1
```

```
      IF (((MS(4).EQ.1).AND.(MS(5).EQ.1)).AND.(M.EQ.M2)) MCB=1
      IF (((MS(4).EQ.0).CR.(MS(5).EQ.0)).AND.(M.EQ.M2)) NC1=NC1-1
      GC TO 285
283   IF (MBK(4,1).NE.1) GO TC 284
      IF (M.NE.M1) GO TO 284
      NCCN(M,N3)=NCON(MBS1,N23)
      NCCN(M,N8)=NC1
      NC1=NC1-1
      GC TO 285
284   IF (MBK(2,3).NE.1) GO TO 286
      IF (M.NE.M2) GO TO 286
      NCCN(M,N8)=NCON(MBS1,N28)
      IF ((MS(4).EQ.0).CR.(MS(5).EQ.0)) NC1=NC1-1
      IF ((MS(4).EQ.1).ANC.(MS(5).EQ.1)) MCB=1
      GC TO 286
285   IF (((M.EQ.M1).AND.(MF(K,1).EQ.1)).AND.(MF(K,8).EQ.1))
     1  NCON(MMIN1,N8)=NCCN(M,N3)
286   MBS1=MBS1+1
      IF (LL.EQ.2) GO TO 300
      IF (M.EQ.M2) NELB(KBK)=NELB(KBK)+NRR(IIIB,I)
      GC TO 3CC
290   NCCN(M,N1)=NC1
      NCCN(M,N12)=NC1+1
      NCCN(M,N11)=NC1+2
      NCCN(M,N10)=NC1+3
      IF ((III.NE.1).AND.(L4.EQ.1)) GC TC 291
      GC TO 3C0
291   IF ((MFB(K,3).EQ.C).AND.(MFB(K,4).EQ.0)) GC TC 300
      IF (M.EQ.M1) MBS1=MEL(KBK,3)
      IF (MBK(3,4).NE.1) GO TO 292
      NCCN(M,1)=NCCN(MBS1,21)
      NCCN(M,12)=NCON(MBS1,32)
      NCCN(M,11)=NCON(MBS1,31)
      NCCN(M,10)=NCON(MBS1,30)
      NC1=NC1-3
      IF(((MS(5).EQ.0).AND.(M.EQ.M2)).AND.(MS(6).NE.1)) NC1=NC1-1
      IF (M.NE.M1) GC TC 294
      IF ((MS(7).EQ.1).ANC.(MS(6).EQ.C)) NC1=NC1+1
      IF (((MS(7).EQ.0).AND.(MS(8).EQ.1)).AND.(MF(KA,6).EQ.1)) NC1=NC1+1
      GC TO 294
292   IF (MFB(K,4).NE.1) GO TO 293
      IF (M.NE.M1) GO TC 294
      NCCN(M,1)=NCON(MBS1,21)
      IF ((MS(7).EQ.1).ANC.(MS(6).EQ.0)) NC1=NC1+1
      IF (((MS(7).EQ.0).AND.(MS(8).EQ.1)).AND.(MF(KA,6).EQ.1)) NC1=NC1+1
      NCCN(M,12)=NC1
      NCCN(M,11)=NC1+1
      NCCN(M,10)=NC1+2
```

```
      NC1=NC1-1
      GO TO 294
293   IF (MFB(K,3).NE.1) GO TO 295
      IF (M.NE.M2) GO TO 295
      NCON(M,10)=NCON(MBS1,30)
      IF (MS(5).EQ.0) NC1=NC1-1
      GO TO 295
294   IF (M.NE.M1) GO TO 295
      IF (MF(K,8).EQ.1) NCON(MMIN1,10)=NCON(M,1)
295   MBS1=MBS1+1
300   NC1=NC1+NKIND1
      NCON(M,33)=NSCON(K,12)
350   CONTINUE
      IF ((II.NE.1).AND.(L3.EQ.1)) GO TO 355
      GO TO 375
355   IF ((MS(2).EQ.0).AND.(MS(3).EQ.0)) GO TO 375
      MM5=MEL(K,2)
      MM6=MEL(KL,4)
      MM7=MEL(KL1,4)
      MM8=MEL(KL2,3)
      MM9=MEL(KL,3)
      MM10=MEL(K,1)
      GO TO (360,365,365),NKIND
360   IF (MS(2).NE.1) GO TO 362
      NCON(MM9,N13)=NCON(MM10,N14)
      IF ((MF(KL,8).EQ.1).AND.(MB(KL,8).EQ.1)) NCON(MM7,N16)=
     1  NCON(MM9,N13)
362   IF (MS(3).NE.1) GO TO 375
      NCON(MM6,N16)=NCON(MM5,N15)
      IF ((MF(KL,5).EQ.1).AND.(MB(KL,5).EQ.1)) NCON(MM8,N13)=
     1  NCON(MM6,N16)
      GO TO 375
365   IF (MS(2).NE.1) GO TO 367
      NCON(MM9,N1)=NCON(MM10,N4)
      IF (MF(KL,8).EQ.1) NCON(MM7, N10)=NCON(MM9,N1)
367   IF (MS(3).NE.1) GO TO 375
      NCON(MM6,N10)=NCON(MM5,N7)
      IF (MF(KL,5).EQ.1) NCON(MM8,N1)=NCON(MM6,N10)
375   IF ((  MS(4).EQ.0).AND.(L3.EQ.1)) NC1=NC1+1
      IF ((((  MS(4).EQ.0).OR.(  MS(5).EQ.0)).AND.(L3.EQ.0))
     1.AND.(LL.NE.LL2)) NC1=NC1+1
      IF (((  MS(5).EQ.0).AND.(  MS(6).NE.1)).AND.(LL.EQ.LL2)) NC1=NC1+1
380   M1=M2+1
390   K=K+1
400   CONTINUE
430   CONTINUE
      MM2=MM1
      MM1=M1
```

```
450   CONTINUE
      KK=K
      GO TO 500
470   KK=KK+NGROW
500   CONTINUE
      KK=KKS
      II=0
      IF ((LLS.EQ.1).AND.(LS.NE.1)) GO TO 505
      GO TO 530
505   DO 520 M=MMS1,M2
      DO 510 IC=1,12
      IC1=IC+20
510   NCON(MMS2,IC1)=NCON(M,IC)
520   MMS2=MMS2+1
530   IF (LLS.NE.LLS1) MM1=MMS1
700   CONTINUE
      MMS2=MMS1
      MMS1=M1
      NP1B=NP1-1
      IF (NP1.NE.1) MPB=NELP(NP1B)
      NP2=NP2+MPB
      NELP(NP1)=M-NP2
      NELGS(IS)=NELGS(IS)+NELP(NP1)
      NP1=NP1+1
800   CONTINUE
890   KKS=KKS+NGROW*NGCOL
      KK=KKS
900   CONTINUE
      NEL=M
      NJT=NCON(NEL,30)
      WRITE (6,13) NEL,NJT
      IF (NJT.GT.MAXNJT) GO TO 990
      WRITE (6,10)
      NBAND=0
      DO 950 I=1,NEL
      MAXB=0
      MINB=MAXNJT+1
      DO 910 J=1,12
910   IF (NCON(I,J).LT.MINB) MINB=NCON(I,J)
      DO 920 K=21,32
920   IF (NCON(I,K).GT.MAXB) MAXB=NCON(I,K)
      NBAND1=MAXB-MINB
      IF (NBAND1.GT.NBAND) NBAND=NBAND1
      IF(NPUNCH.EQ.0) GO TO 950
      WRITE (7,11) (NCON(I,IN),IN=1,33)
950   WRITE (6,12) I,(NCON(I,IN),IN=1,33)
      NBAND=(NBAND+1)*3
      WRITE (6,975) NBAND
```

```
975  FCRMAT (///,' HALF BAND WIDTH FCR TRISOP STIFFNESS MATRIX=',I5)
     RETURN
98C  NSTCP=1
     WRITE (6,985) MAXNEL
985  FCRMAT (///,' DATA REJECTED***NUMBER OF ELEMENTS GREATER THAN',I5
    1,/,' ***********************************************************')
     RETURN
990  NSTCP=1
     WRITE (6,995) MAXNJT
995  FCRMAT (///,' DATA REJECTED***NUMBER OF JCINTS GREATER THAN',I5
    1,/,' ***********************************************************')
     RETURN
     END



     SUBROUTINE COORD
C
C       THIS SUBROUTINE DETERMINES X,Y&Z COORDINATES OF JCINTS.
C       OUTPUT IS PRINTED WITH AN OPTICN TO PUNCH IN FORMAT
C       COMPATIBLE WITH 'TRISOP'.
C
     IMPLICIT REAL*8 (A-H,O-Z)
     IMPLICIT INTEGER*2 (I-N)
     DIMENSICN ND1(12),ND2(4),ND3(4),ND4(12),ND5(12),ND6(4),ND7(4),
    1ND8(12),ND9(12),ND10(4),ND11(4),NC12(12)
     DIMENSICN XI(32),ETA(32),ZETA(32)
     CCMMON/ INT/NPT,NEL,NPUNCH,NSTOP,NJT,NPLOT,NKIND,NSEL,NGRCW,NGCCL,
    1NGSLCE
     CCMMON/MESH1/ NSCON(125,13), MF(125,8), ME(125,8), MFB(125,4),
    1MEA(125,4),  MEL(125,4),  NELB( 125),  NELP(125)
     CCMMON/MESH2/ NRR(5,5),NCR(5,5),NSR(5),NELGS(5)
     CCMMON/MESH3/ NCON(200,33)
     CCMMCN/CORD1/CORD(1296,3)
     CCMMCN/CCRD2/BOUND(200,3)
     CCMMON/SF/ VAL(32)
     DATA ND5/1,2,3,4,13,14,17,18,21,22,23,24/
     DATA ND6/5,12,25,32/
     DATA ND7/6,11,26,31/
     DATA ND8/10,9,8,7,16,15,20,19,30,29,28,27/
     DATA ND9/1,2,3,4,5,6,7,8,9,10,11,12/
     DATA ND10/13,14,15,16/
     DATA ND11/17,18,19,20/
     DATA ND12/21,22,23,24,25,26,27,28,29,30,31,32/
     DATA ND1/4,5,6,7,14,15,18,19,24,25,26,27/
     DATA ND2/3,8,23,28/
```

```
      DATA ND3/2,9,22,29/
      CATA ND4/1,12,11,1C,13,16,17,20,21,32,31,3C/
 20   FCRMAT (///,' COORDINATES CF JOINTS',//,' JCINT NUMBER',8X,
     1'X COORDINATE',5X,'Y CCORDINATE',5X,'Z CCCRDINATE',//)
 30   FCRMAT (5X,I3,12X,G14.5,2(3X,G14.5))
 40   FCRMAT (6X,I10,3F15.5)
C
C
      LL=1
      J1=1
      K=1
C
C        GRID SLICE
C
      CC 900 L=1,NGSLCE
      IF (NSR(L).EQ.0) GC TO 890
      J2=J1+NSR(L)-1
C
C        GRID CCLUMN
C
      CC 800 NK=1,NGCOL
      IF (NCR(L,NK).EQ.0) GO TO 790
C
C        GRID ROW
C
      DC 700 M=1,NGROW
      IF (NSCCN(K,1).EQ.0) GO TO 700
      NPTB=NSCON(K,13)
      CELXI =2.DO/(3*NSCCN(K,2))
      DELETA=2.DO/(3*NSCON(K,1))
      CELZET=2.DO/(3*NSCCN(K,3))
      XIVAL =-1.DO
      ETAVAL=1.DO
      ZETVAL=1.DO
      N2=NSCON(K,2)
C
C        SUPER ELEMENT SLICE
C
      CC 600 J=J1,J2
      IF (J.NE.J1) GO TC 50
      NK1=MEL(K,1)-NELGS(L)+NELP(J)
      I1=NK1
C
C        SUPER ELEMENT CCLUMNS
C
 50   CC 500 N=1,N2
      I2=I1+NSCCN(K,1)-1
C
```

```
C         SUPER ELEMENT RCWS
C
      DC 400 I=I1,I2
      CC 100 MM=1,12
      L1=ND1(MM)
 100  XI(L1)=XIVAL
      CC 120 MM=1,4
      L1=ND2(MM)
 120  XI(L1)=XIVAL+DELXI
      DC 140 MM=1,4
      L1=ND3(MM)
 140  XI(L1)=XIVAL+2*DELXI
      CC 150 MM=1,12
      L1=ND4(MM)
 150  XI(L1)=XIVAL+3*DELXI
      DC 160 MM=1,12
      L1=ND5(MM)
 160  ETA(L1)=ETAVAL
      DC 180 MM=1,4
      L1=ND6(MM)
 180  ETA(L1)=ETAVAL-DELETA
      CC 200 MM=1,4
      L1=ND7(MM)
 200  ETA(L1)=ETAVAL-2*DELETA
      CC 210 MM=1,12
      L1=ND8(MM)
 210  ETA(L1)=ETAVAL-3*DELETA
      CC 220 MM=1,12
      L1=ND9(MM)
 220  ZETA(L1)=ZETVAL
      CC 240 MM=1,4
      L1=ND10(MM)
 240  ZETA(L1)=ZETVAL-DELZET
      CC 260 MM=1,4
      L1=ND11(MM)
 260  ZETA(L1)=ZETVAL-2*DELZET
      CC 270 MM=1,12
      L1=ND12(MM)
 270  ZETA(L1)=ZETVAL-3*DELZET
      CC 350 MM=1,32
      L2=NCON(I,MM)
      XI1=XI(MM)
      ETA1=ETA(MM)
      ZETA1=ZETA(MM)
      CALL SHAPE (XI1,ETA1,ZETA1,NPTB)
      CCRD(L2,1)=0.D0
      CCRD(L2,2)=0.D0
      CCRD(L2,3)=0.D0
```

```
      LLL=LL
      DO 300 NN=1,NPTB
      CORD(L2,1)=CORD(L2,1)+VAL(NN)*BOUND(LLL,1)
      CORD(L2,2)=CORD(L2,2)+VAL(NN)*BOUND(LLL,2)
      CORD(L2,3)=CORD(L2,3)+VAL(NN)*BOUND(LLL,3)
300   LLL=LLL+1
350   CONTINUE
      ETAVAL=ETAVAL-3*DELETA
400   CONTINUE
      ETAVAL=1.D0
      I1=I1+NRR(L,NK)
      XIVAL=XIVAL+3*DELXI
500   CONTINUE
      XIVAL=-1.D0
      NK1=NK1+NELP(J)
      I1=NK1
      ZETVAL=ZETVAL-3*DELZET
600   CONTINUE
      ZETVAL=1.D0
      LL=LL+NPTB
700   K=K+1
      GO TO 800
790   K=K+NGROW
800   CONTINUE
      J1=J2+1
      GO TO 900
890   K=K+NGROW*NGCOL
900   CONTINUE
      WRITE (6,20)
      DO 950 I=1,NJT
      IF (NPUNCH.EQ.0) GO TO 950
      WRITE (7,40) I,(CORD(I,J),J=1,3)
950   WRITE (6,30) I,(CORD(I,J),J=1,3)
      RETURN
      END
```

```
      SUBROUTINE SHAPE (X,Y,Z,NBNCDE)
      IMPLICIT REAL*8 (A-H,O-Z)
      IMPLICIT INTEGER*2 (I-N)
      DIMENSION XYZL(8,3),XYZQ(20,3),XYZC(32,3),IPERM(16)
      COMMON/SF/VAL(32)
      DATA XYZL/1.0D0,-1.0D0,-1.0D0,1.0D0,1.0D0,-1.0D0,-1.0D0,1.0D0,
     11.0D0,1.0D0,-1.0D0,-1.0D0,1.0D0,1.0D0,-1.0D0,-1.0D0,1.0D0,1.0D0,
     21.0D0,1.0D0,-1.0D0,-1.0D0,-1.0D0,-1.0D0/
      DATA XYZQ/1.0D0,0.0D0,-1.0D0,-1.0D0,-1.0D0,0.0D0,1.0D0,1.0D0,
     11.0D0,-1.0D0,-1.0D0,1.0D0,1.0D0,0.0D0,-1.0D0,-1.0D0,-1.0D0,0.0D0,
     21.0D0,1.0D0,1.0D0,1.0D0,1.0D0,0.0D0,-1.0D0,-1.0D0,-1.0D0,0.0D0,
     31.0D0,1.0D0,-1.0D0,-1.0D0,1.0D0,1.0D0,1.0D0,0.0D0,-1.0D0,-1.0D0,
     4-1.0D0,0.0D0,1.0D0,1.0D0,1.0D0,1.0D0,1.0D0,1.0D0,1.0D0,1.0D0,
     50.0D0,0.0D0,0.0D0,0.0D0,-1.0D0,-1.0D0,-1.0D0,-1.0D0,-1.0D0,-1.0D0,
     6-1.0D0,-1.0D0/
      DATA XYZC/1.0D0,.3333333333333333D0,-.3333333333333333D0,-1.0D0,
     1-1.0D0,-1.0D0,-1.0D0,-.3333333333333333D0,.3333333333333333D0,
     21.0D0,1.0D0,1.0D0,1.0D0,-1.0D0,-1.0D0,1.0D0,1.0D0,-1.0D0,-1.0D0,
     31.0D0,1.0D0,.3333333333333333D0,-.3333333333333333D0,-1.0D0,-1.0D0,
     4-1.0D0,-1.0D0,-.3333333333333333D0,.3333333333333333D0,1.0D0,1.0D0,
     51.0D0,1.0D0,1.0D0,1.0D0,1.0D0,.3333333333333333D0,
     6-.3333333333333333D0,-1.0D0,-1.0D0,-1.0D0,-1.0D0,
     7-.3333333333333333D0,.3333333333333333D0,1.0D0,1.0D0,-1.0D0,-1.0D0,
     81.0D0,1.0D0,-1.0D0,-1.0D0,1.0D0,1.0D0,1.0D0,1.0D0,
     9.3333333333333333D0,-.3333333333333333D0,-1.0D0,-1.0D0,-1.0D0,
     A-1.0D0,-.3333333333333333D0,.3333333333333333D0,1.0D0,1.0D0,1.0D0,
     B1.0D0,1.0D0,1.0D0,1.0D0,1.0D0,1.0D0,1.0D0,1.0D0,1.0D0,
     C.3333333333333333D0,.3333333333333333D0,.3333333333333333D0,
     D.3333333333333333D0,-.3333333333333333D0,-.3333333333333333D0,
     E-.3333333333333333D0,-.3333333333333333D0,-1.0D0,-1.0D0,-1.0D0,
     F-1.0D0,-1.0D0,-1.0D0,-1.0D0,-1.0D0,-1.0D0,-1.0D0,-1.0D0,-1.0D0/
      DATA IPERM/2,3,8,9,22,23,28,29,5,6,11,12,25,26,31,32/
      FL (X,Y,Z,X1,Y1,Z1) = (1.0D0+X*X1)*(1.0D0+Y*Y1)*(1.0D0+Z*Z1)/.8D1
      FQC(X,Y,Z,X1,Y1,Z1) = (1.0D0+X*X1)*(1.0D0+Y*Y1)*(1.0D0+Z*Z1)*
     1(X*X1+Y*Y1+Z*Z1-.2D1)/.8D1
      FQM(X,Y,Z,   Y1,Z1) = (1.0D0-X*X)*(1.0D0+Y*Y1)*(1.0D0+Z*Z1)/.4D1
      FCC(X,Y,Z,X1,Y1,Z1) = (1.0D0+X*X1)*(1.0D0+Y*Y1)*(1.0D0+Z*Z1)*
     1(.9D1*(X*X+Y*Y+Z*Z)-1.9D1)/6.4D1
      FCM(X,Y,Z,X1,Y1,Z1) = (1.0D0-X*X)*(1.0D0+.9D1*X*X1)*(1.0D0+Y*Y1)*
     1(1.0D0+Z*Z1)*.9D1/6.4D1
      IF (NBNCDE.EQ.32) GO TO 500
      IF (NBNCDE.EQ.20) GO TO 200
C
C        LINEAR FUNCTIONS
C
      DO 100 I=1,8
      X1=XYZL(I,1)
      Y1=XYZL(I,2)
```

```
      Z1=XYZL(I,3)
 10C  VAL(I)=FL(X,Y,Z,X1,Y1,Z1)
      RETURN
C
C        QUADRATIC FUNCTICNS
C
 20C  DC 250 I=1,7,2
      J=I+12
      X1=XYZQ(I,1)
      Y1=XYZQ(I,2)
      Z1=XYZQ(I,3)
      X2=XYZQ(J,1)
      Y2=XYZQ(J,2)
      Z2=XYZQ(J,3)
      VAL(I)=FGC(X,Y,Z,X1,Y1,Z1)
 250  VAL(J)=FQC(X,Y,Z,X2,Y2,Z2)
      DC 300 I=2,6,4
      J=I+12
      Y1=XYZQ(I,2)
      Z1=XYZQ(I,3)
      Y2=XYZQ(J,2)
      Z2=XYZQ(J,3)
      VAL(I)=FGM(X,Y,Z,Y1,Z1)
 300  VAL(J)=FQM(X,Y,Z,Y2,Z2)
      DC 350 I=4,8,4
      J=I+12
      X1=XYZQ(I,1)
      Z1=XYZQ(I,3)
      X2=XYZQ(J,1)
      Z2=XYZQ(J,3)
      VAL(I)=FQM(Y,Z,X,Z1,X1)
 350  VAL(J)=FQM(Y,Z,X,Z2,X2)
      DC 400 I=9,12
      X1=XYZQ(I,1)
      Y1=XYZQ(I,2)
 400  VAL(I)=FGM(Z,X,Y,X1,Y1)
      RETURN
C
C        CUBIC FUNCTIONS
C
 50C  DC 550 I=1,10,3
      J=I+20
      X1=XYZC(I,1)
      Y1=XYZC(I,2)
      Z1=XYZC(I,3)
      X2=XYZC(J,1)
      Y2=XYZC(J,2)
      Z2=XYZC(J,3)
```

```
      VAL(I)=FCC(X,Y,Z,X1,Y1,Z1)
550   VAL(J)=FCC(X,Y,Z,X2,Y2,Z2)
      CC 600 I=1,8
      II=IPERM(I)
      X1=XYZC(II,1)
      Y1=XYZC(II,2)
      Z1=XYZC(II,3)
600   VAL(II)=FCM(X,Y,Z,X1,Y1,Z1)
      CC 650 I=9,16
      II=IPERM(I)
      X1=XYZC(II,1)
      Y1=XYZC(II,2)
      Z1=XYZC(II,3)
650   VAL(II)=FCM(Y,Z,X,Y1,Z1,X1)
      CC 700 I=13,20
      X1=XYZC(I,1)
      Y1=XYZC(I,2)
      Z1=XYZC(I,3)
700   VAL(I)=FCM(Z,X,Y,Z1,X1,Y1)
      RETURN
      END




      SUBROUTINE TRFR(TETA,ALPHA,BETA)
      IMPLICIT REAL*8 (A-H,O-Z)
      IMPLICIT INTEGER*2 (I-N)
      CCMMON/INT/NPT,NEL,NPUNCH,NSTOP,NJT,NPLCT,NKIND,NSEL,NGRCW,NGCOL,
     1NGSLCE
      CCMMON/CCRC1/CORD(1296,3)
      DIMENSICN TFORM(3,3),DUM(3)
      CTET=DCCS(TETA)
      STET=DSIN(TETA)
      CALP=DCCS(ALPHA)
      SALP=DSIN(ALPHA)
      CBET=DCCS(BETA)
      SBET=DSIN(BETA)
      TFCRM(1,1)=CTET*CBET-SALP*STET*SBET
      TFCRM(1,2)=STET*CBET+SALP*CTET*SBET
      TFCRM(1,3)=-SBET*CALP
      TFCRM(2,1)=-STET*CALP
      TFCRM(2,2)=CALP*CTET
```

```
      TFORM(2,3)=SALP
      TFORM(3,1)=SBET*CTET+STET*SALP*CBET
      TFORM(3,2)=STET*SBET-SALP*CTET*CBET
      TFORM(3,3)=CALP*CBET
      DO 300 I=1,NJT
      DO 100 J=1,3
      DUM(J)=0.0D0
      DO 100 K=1,3
  100 DUM(J)=DUM(J)+TFORM(J,K)*CORD(I,K)
      DO 200 J=1,3
  200 CORD(I,J)=DUM(J)
  300 CONTINUE
      RETURN
      END




      SUBROUTINE GRID
      IMPLICIT REAL*8 (A-H,O-Z)
      IMPLICIT INTEGER*2 (I-N)
      INTEGER*4 N1,MC,ITYPE,IXUP,IYRT,MCXAX,MDYAX,IWIDE,IHIGH,IGRID,LAST
      INTEGER*4 NJJ
      REAL*4 X,Y,XSCALE,YSCALE
      REAL LABEL/4H    /
      DIMENSION X(33),Y(33),ISIX(2,3)
      DIMENSION NPC(4),INCC(4)
      COMMON/TITL/TITLE(12)
      COMMON/MESH3/ NCON(200,33)
      COMMON/INT/NPT,NEL,NPUNCH,NSTOP,NJT,NPLOT,NKIND,NSEL,NGROW,NGCOL,
     1NGSLCE
      COMMON/CORD1/CORD(1296,3)
      DATA ISIX/1,2,2,3,3,1/
      DATA NPC/1,13,17,21/
      DATA INCC/3,1,1,3/
      DATA ITYPE/0/ ,IXUP/15/,IYRT/0/ ,MDXAX/2/ ,MDYAX/2/ ,IWIDE/9/ ,
     1IHIGH/15/ ,IGRID/0/
      NKIND=3
      NPT=32
      DO 180 II=1,3
      XMAX=-1.0D+20
      YMAX=-1.0D+20
      XMIN= 1.0D+20
      YMIN= 1.0D+20
      I1=ISIX(1,II)
      I2=ISIX(2,II)
      DO 20 I=1,NJT
```

```
      XMAX=DMAX1(XMAX,CORD(I,I1))
      YMAX=DMAX1(YMAX,CORD(I,I2))
      XMIN=DMIN1(XMIN,CCRD(I,I1))
 2C   YMIN=DMIN1(YMIN,CORD(I,I2))
      IF (XMIN.GE.O.DO) GO TO 40
      XMAX=XMAX-XMIN
      DC 30 I=1,NJT
 30   CCRD(I,I1)=CORD(I,I1)-XMIN
 40   IF (YMIN.GE.O.DO) GO TC 60
      YMAX=YMAX-YMIN
      DC 50 I=1,NJT
 50   CCRD(I,I2)=CORD(I,I2)-YMIN
   60 CCNTINUE
 110  XSCALE=1.5DO*(YMAX/9.DO)
      YSCALE=1.5DO*(XMAX/15.DC)
      IF (XSCALE.GT.YSCALE) YSCALE=XSCALE
      IF (XSCALE.LT.YSCALE) XSCALE=YSCALE
      NI=(NPT+4)/3 + 1
      MC=1
      MSTCP=0
      DC 170 I=1,NEL
      IF (I.EQ.NEL) MSTCP=3
C
      JT=N1-1
      DC 120 J=1,JT
      J1=NCON(I,J)
      IF (J.EQ.1) J2=J1
      X(J)=CCRD(J1,I2)
 120  Y(J)=-CCRD(J1,I1)
      J=J+1
      X(J)=CCRD(J2,I2)
      Y(J)=-CCRD(J2,I1)
      CALL DRAW (N1,X ,Y ,MC,ITYPE,LABEL,TITLE,XSCALE,YSCALE,IXUP,IYRT,
     1MCXAX,MCYAX,IWIDE,IHIGH,IGRIC,LAST)
      MC=2
      JL=2*JT-3
      JTT=JL+JT-1
      DC 130 J=JL,JTT
      J1=NCON(I,J)
      IF (J.EQ.JL) J2=J1
      M=J-JL+1
      X(M)=CCRD(J1,I2)
 130  Y(M)=-CCRD(J1,I1)
      M=M+1
      X(M)=CCRD(J2,I2)
      Y(M)=-CCRD(J2,I1)
      CALL DRAW (N1,X ,Y ,MC,ITYPE,LABEL,TITLE,XSCALE,YSCALE,IXUP,IYRT,
     1MCXAX,MCYAX,IWIDE,IHIGH,IGRID,LAST)
```

```
      DO 160  JJJ=1,4
      JJ1=NKIND+1
      DO 150  JJ=1,JJ1
      J1=NPC(JJ)+INCC(JJ)*(JJJ-1)
      IF((MSTOP.EQ.3).AND.(JJJ.EQ.4))   MC=3
      JX=NCON(I,J1)
      X(JJ)=CORD(JX,I2)
  150 Y(JJ)=-CORD(JX,I1)
      NJJ=JJ
      CALL DRAW(NJJ,X  ,Y  ,MC,ITYPE,LABEL,TITLE,XSCALE,YSCALE,IXUP,IYRT,
     1MCXAX,MCYAX,IWIDE,IHIGH,IGRID,LAST)
  160 CONTINUE
  170 CONTINUE
  180 CONTINUE
      RETURN
      END
```

REFERENCES

1. Zienkiewicz, O. C., The Finite Element Method, McGraw-Hill Publishing Company, Ltd., London, 1971

2. Cantin, G., Three Dimensional Finite Element Studies, Part One: Service Routines, Naval Postgraduate School, Monterey, California, December, 1972.

3. Zienkiewicz, O. C. and Phillips, D. V., "An Automatic Mesh Generation Scheme for Plane and Curved Surfaces by 'Isoparametric' Co-Ordinates," International Journal for Numerical Methods in Engineering, Vol. 3, No. 4, October-December 1971.

4. Hanson, D. E., Three-Dimensional Elastostatic Problems Using Isoparametric Finite Elements, Master's Thesis, Naval Postgraduate School, Monterey, California, 1971.

5. Leonidas, E., A General Purpose Three-Dimensional Stress Analysis Program, Master's Thesis, Naval Postgraduate School, Monterey, California 1971.

6. Dean, D. V., Finite Element Study of Acoustic Waves, Master's Thesis, Naval Postgraduate School, Monterey, California, 1970.

INITIAL DISTRIBUTION LIST

		No. Copies
1.	Defense Documentation Center Cameron Station Alexandria, Virginia 22314	2
2.	Library, Code 0201 Naval Postgraduate School Monterey, California 93940	2
3.	Professor Gilles Cantin Naval Postgraduate School Monterey, California 93940	5
4.	Professor Robert E. Newton Naval Postgraduate School Monterey, California 93940	1
5.	Asst. Prof. David Salinas Naval Postgraduate School Monterey, California 93940	1
6.	Assoc. Prof. Robert H. Nunn Naval Postgraduate School Monterey, California 93940	1
7.	W. R. Church Computer Center Naval Postgraduate School Monterey, California 93940	2
8.	Dr. Arnold Adicoff Naval Weapons Center China Lake, California 93555	2
9.	Mr. Kenneth Bischell Naval Weapons Center China Lake, California 93555	1
10.	Mr. J. E. Serpanos Naval Weapons Center China Lake, California 93555	1
11.	Dr. Murray Naval Ships Research and Development Center Washington, D.C. 20007	1
12.	Dr. Elizabeth Cuthill Naval Ships Research and Development Center Washington, D.C. 20007	1

13. Mr. Petro Matula 1
Naval Ships Research and Development Center
Washington, D.C. 20007

14. Technical Library 1
Naval Ships Research and Development Center
Washington, D.C. 20007

15. Dr. Nicholas Perrone 1
Office of Naval Research
Ballston Centre Tower #1
Washington, D.C. 20007

16. Dr. Leila Brown 1
Office of Naval Research
Ballston Centre Tower #1
Washington, D.C. 20007

17. Mr. Wallace Dietrich 1
Naval Ships Engineering Center
701 CTRBG
Hyattsville, Maryland 21281

18. LCDR Charles B. Anthony 1
Naval Ships Engineering Center
701 CTRBG
Hyattsville, Maryland 21281

19. Technical Library 1
Naval Weapons Laboratory
Dahlgren, Virginia 22448

20. Mr. Alexander Elder 1
Ballistics Research Laboratory
Aberdeen Proving Ground
Aberdeen, Maryland 21005

21. Technical Library 1
Naval Ordnance Laboratory-White Oak
Silver Spring, Maryland 20910

22. Technical Library 1
Naval Air Development Center
Wurminster, Pennsylvania 18974

23. Mr. J. Philip Raney 1
NASA Langley Research Center
Hampton, Virginia 23365

24. LCDR Girard T. Lew 1
Supervisor of Shipbuilding, Conversion
and Repair
Pascagoula, Mississippi 39567

25. LCDR L. J. Smith 1
SMC 1905
Naval Postgraduate School
Monterey, California 93940

26. LT D. A. Smith 1
SMC 2469
Naval Postgraduate School
Monterey, California 93940

27. LT James R. Adamek 2
SMC 2194
Naval Postgraduate School
Monterey, California 93940

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

ORIGINATING ACTIVITY *(Corporate author)* Naval Postgraduate School Monterey, California 93940	2a. REPORT SECURITY CLASSIFICATION Unclassified 2b. GROUP

REPORT TITLE

AN AUTOMATIC MESH GENERATOR USING TWO AND THREE-DIMENSIONAL ISOPARAMETRIC FINITE ELEMENTS

DESCRIPTIVE NOTES *(Type of report and inclusive dates)*

Master's Thesis; June 1973

AUTHOR(S) *(First name, middle initial, last name)*

James R. Adamek; Lieutenant, United States Navy

REPORT DATE June 1973	7a. TOTAL NO. OF PAGES 155	7b. NO. OF REFS 6

CONTRACT OR GRANT NO.	9a. ORIGINATOR'S REPORT NUMBER(S)
b. PROJECT NO.	
c.	9b. OTHER REPORT NO(S) *(Any other numbers that may be assigned this report)*
d.	

DISTRIBUTION STATEMENT

Approved for public release; distribution umlimited.

SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY Naval Postgraduate School Monterey, California 93940

ABSTRACT

The objective of the project described in this report was to develop computer systems which would generate the element connectivity, and nodal point coordinates for two and three-dimensional finite element programs using isoparametric finite elements. The computer systems and sample problems are discussed.

KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
AUTOMATIC MESH GENERATOR						
ISOPARAMETRIC FINITE ELEMENTS						

Adamek

An automatic mesh generator using two and three-dimensional isoparametric finite elements.

Thesis
A224
c.1

143489

Adamek

An automatic mesh generator using two and three-dimensional isoparametric finite elements.